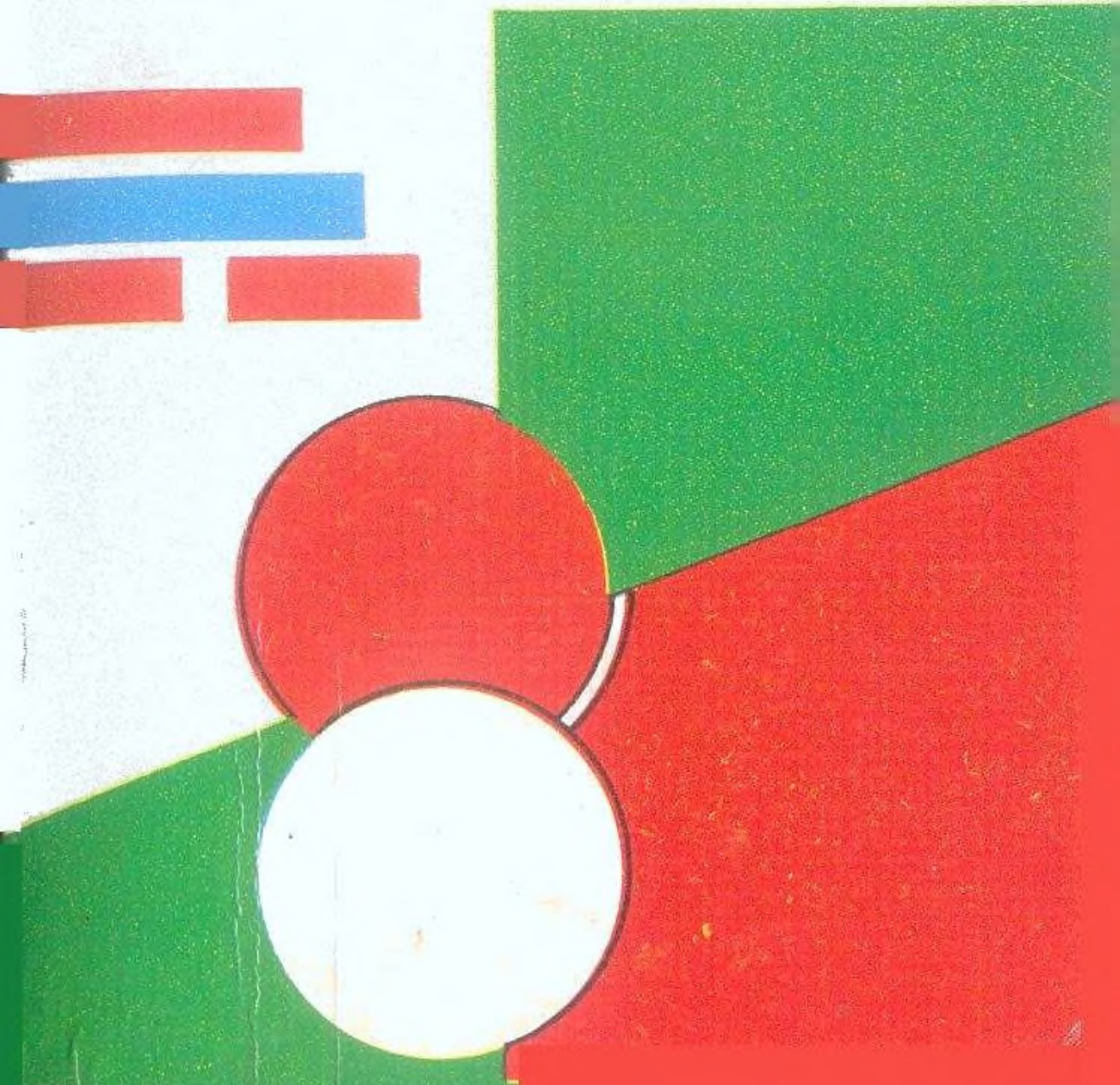
SAHNI'S MINI SERIES

CHEMISTRY FORMULAE



SAHNI'S

CHEMISTRY FORMULAE

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ahni Publications
Dr. Mitra Gali Roashanara Road,,
Delhi - 110007

Publisher
Sahni Publications
4777, Dr Mitra Gali
Roashanara Road
Dehli - 110007

Ph 7434717
2520751

EDITION 1998

© Publisher

ISBN 81-7564-097-9

by: **Computer Codes,**
Mukerjee Nagar, Delhi - 110009

PRINTED BY : S. V. OFFSET WORKS
KARTAR NAGAR DELHI-53
PHONE : 2173220

PREFACE

Although many treatises are available in the market, but few serve the purpose of those students who want to go in for a quick revision in the face of time constraints. This book certainly steps in at that moment and serves that purpose.

The book presents the subject in a simple and brief way to be digested by the students.

At the same time it provides a large number of terms and definitions. In short it is a ready recknor.

The book will not only help those appearing in their school examinations but also prepare them for the various competitive tests in this age of competition.

The book has been based on the syllabus of the U.P. Board, CBSE and NCERT

I have no doubt that the students would be immensely benefitted by the book.

I would like to invite constructive suggestions from readers so that necessary additions could be incorporated in future editions.

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COMPOSITION OF MATTER

Chemistry. is the branch of science which deals with the composition, preparation and properties of the substances.

Branches of Chemistry. There are 7 branches of Chemistry they are (1) Inorganic chemistry (2) Physical chemistry (3) Organic chemistry (4) Biochemistry (5) Analytical chemistry (6) Industrial chemistry (7) Agricultural chemistry.

Role of Chemistry. Chemistry is playing a great role in human life. Some of them are—

Chemistry has solved growing population by new birth controlling drugs.

Chemists have developed new fertilizers and effective insecticides for better agricul-

ture. Hence chemistry is giving food to millions

Chemists have saved man from dreadful diseases. They have produced wonderful drugs like vitamins pencillin, harmones etc.

Founder of modern chemistry. is Lavoisier and the originator of chemistry was Rober Boyle.

Matter. Anything which occupies space and has weight is matter. Sand, water, oxygen, wood, rock are all different kinds of matter because all of them occupy space and have mass. All types of solids, liquids and gases are different kind of matters.

Classification of matter. All the matter can be classified into different classes: element, compound and mixture on the basis of their properties.

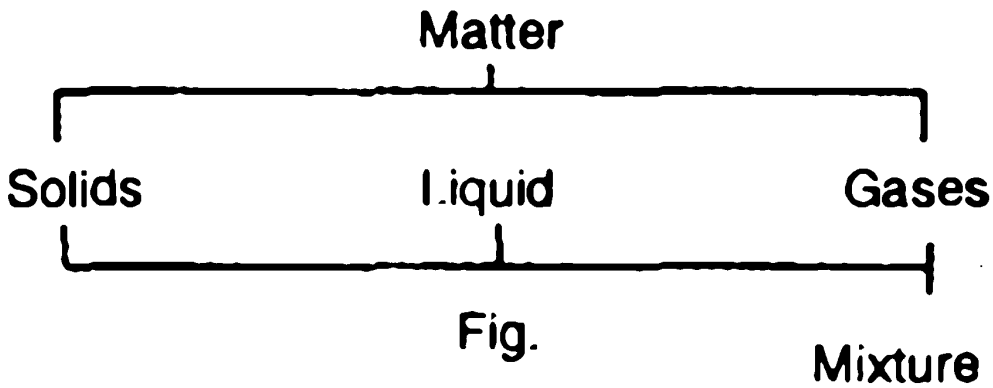


Fig.

Pure substance. A pure substance has one kind of atoms or molecules. A pure substance has a fixed composition and fixed boiling and melting points and does not posses any impurity.

Element. An element is a substance which can not be split up into two or more substance by usual chemical methods of applying heat, light or electric energy.

Types of elements. Elements can be divided into metals and non-metals. All the metals are solids except mercury which is a liquid. Otherwise they possess 1, 2, or 3 electrons in out most orbit. Hydrogen, oxygen, carbon and chlorine are some of the non-metallic elements. The inert gases like neon, helium, argon etc. also non-metallic. All the non-metals are solids or gases but bromine is a liquid.

Chemical Symbol. The symbol of an element is the "first letter or the first letter of another letter" of the English name or Latin name of the element. The symbols of few metals are Iron (Fe). Oxygen (O) copper

(Cu), Silver (Ag), Aluminium (Al) and Zinc (Zn). The first letter of the symbols is always kept in capital, while other letters are small letters. The symbol of oxygen is O (first letter of name). The symbol of copper is Cu (From Latin name cuprum).

Atomic mass of an element. It is defined as how many times the mass of an element is heavier as compared to carbon taken as 12. For example, the atomic mass of magnesium is 24 which indicates that one atom of magnesium is 24 times heavier than 1/12 of a carbon-12 atom. (Atomic mass unit and atomic weight unit are just the same.)

Gram atomic mass. Atomic mass of an element expressed in grams is known as gram atomic mass. (Gram atomic mass is also known as gram atomic weight.)

Mixture. A mixture is a substance that contains two or more elements or compounds but they are not chemically combined together. Air is a mixture of N_2O_2 oxygen, argon, water vapour carbon-dioxide etc. Mixtures are of two types

(i) Homogeneous mixture (ii) Heterogeneous mixture.

Homogeneous mixture. A homogeneous mixture has a uniform composition throughout its mass. And it has no visible boundries of separation between the various constivisible boundaries of separation between the various constituens. A mixture of sugar dissolved in water is a homogeneous mixture.

Heterogeneous mixture. A substance having different composition through out its mass is known as a heterogeneous. It has visible boundaries of separation between the various constituents. A mixture of sand and cement is an example of heterogeneous mixture.

Compound. A compound is a substance which contains two or more elements chemically combined in a fixed proportion by weight. For example water (H_2O) Hydrochloric acid (HCl) are compounds made up of two elements, hydrogen and oxygen chemically combined in a fixed proportion of 1 : 8 by weight.

Difference between a mechanical mixture and a chemical compound

Mixture	*Compounds*
In a mixture, the components may be present in any proportion	If contains same elements combined together in the same proportion by weight.
A mixture is generally heterogeneous so that its constituents can be separated from each other by simple mechanical means.	A chemical compound is homogeneous and its constituents can not be separated by mechanical means. They can be separated by means of chemical actions only.
Usually no energy is given up or formed during the fomation of a mixture.	Energy (in the form of heat or light) is usually given out or absorbed during the preparation of a compound.

Mixture	*Compounds*
A mixture here fixed melting point, boiling point etc.	Compound have fixed melting point, boiling point etc.

Atom. A smallest particle of an element that may or may not have physical existance but can take part in a chemical reaction is known as Atom.

Molecule. The smallest particle of a substance that is capable of physical existance is known as a molecule. Molecules are composed of atoms. A few examples of molecules are oxygen (O_2), hydrogen (H_2), nitrogen (N_2), sodium chloride (NaCl), methane (CH_4) etc.

They are of 2 types—

(i) The molecule of a compound contains two (or more) different types of atoms.

(ii) The molecule of an element contains two (or more) similar atoms.

Gram molecular mass. The molecular

mass of a substance in grams is known as "gram molecular mass."

Chemical formulae. A chemical formula represents the composition of a molecule of the matter in terms of the symbols of the elements present in the molecule.

(i) ***Formula of element.*** One molecule of hydrogen element contains two atoms of hydrogen, therefore the formula of hydrogen is H_2.

(ii) ***Formula of compound.*** Water is a compound whose molecule contains 2 atoms of hydrogen and 1 atom of oxygen. Thus the formula of water is H_2O.

Molecular Mass. The number of times, a molecule of the compound is heavier than 1/12 of the mass of a carbon-12 atom.

Calculation of molecular mass. The molecular mass is equal to sum of the atomic masses of all the atoms present in one molecule of the substance.

Chemical **equations.** The method of representing a chemical reaction with the

help of symbols and formulae of the substances involved in it is known as a chemical equation.

Reactant. The substances which combine or react are known as reactants.

Products. The new substances produced in a reaction are known as products.

Balanced chemical equation. A balanced equation has an equal number of atoms of different elements in the reactants and products.

Unbalanced chemical equation. An unbalanced chemical equation has an unequal number of atoms of one or more elements in the reactants and products. The example of unbalanced equation is:

$$H_2O \longrightarrow H_2O.$$

Balancing of a Chemical equation. The process of making the number of different types of atoms equal on both the sides of an equation is known as the balancing of a equation. There are two methods of balancing the equation (i) by hit and trial method (ii) by partial equation method.

The Mole. A group of 6.023×10^{23} particles (may be atoms or molecules) of a substance is known as a mole of that substance.

States of matter. There are three physical states of matter.

(i) Solids (ii) Liquids and

(iii) Gases.

(i) *Solids.* Solids have definite shape and volume because atoms and molecules are closely packed in a systematic way. Its-each atom and molecule has a fixed position not free to move. e.g. book, chair, copper, wood etc.

(ii) *Liquids.* In liquids molecules are also close to each other. This is why liquids have definite volume. But molecular arrangement in liquid is different from solids. Molecules in a liquid are free to move that is why liquids are fluid and can take any shape. e.g. water, milk etc.

(iii) *Gases.* Gases have neither a fixed volume nor fixed shape. The molecules remain far apart from each other and are free

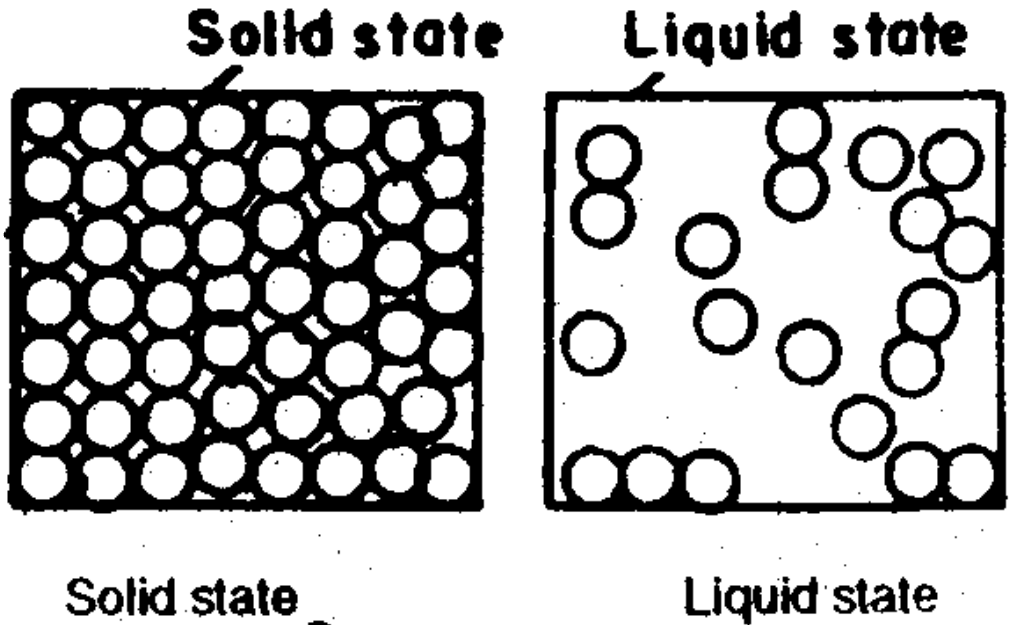


Fig. Gaseous state

to move because of weak inter-molecular forces. It takes the shape of container and fills it completely e.g. oxygen, nitrogen, air etc.

Volume of a gas. The volume of a gas is always equal to the volume of its container. The S.I. unit of volume is "cubic meter" which is written as m^3. $1\ m^3 = 10^6\ cm^3$.

Pressure of a gas. A gas enclosed in a vessel exerts a force on its wall. This force per unit area is known as gas pressure.

The common unit of pressure is "mill meter of mercury *i.e.*, mm of mercury (mm-Hg) or just mm.

The mm of mercury pressure is also called by the name torr. Another common unit of measurement of pressure is 'atmosphere' The unit of pressure called atmosphere is defined as that pressure which supports a column of mercury 760 mm high at 0°C and at sea level. So 1 atmosphere is equal to 760 mm of Hg.

The S.I. unit of pressure is *pascal* which is denoted by symbol Pa.

$$1\ atm = 1\,013 \times 10^5\ N/m^2 \quad or$$

$$1\ atm = 1{\cdot}013 \times 10^5\ Pa.$$

There is also another unit called 'bar' has been derive from S.I. unit of pressure.

$1 \text{ bar} = 10^5 \text{ N/m}^2$ *or*

1 atom = 1·013 bar.

Temperature of a gas. The molecules of a gas are in motion and possesses kinetic energy.

The common unit of temperature is degree celsius" or degree centigrate which is written in short form as ° C.

The S.I. unit of temperature is known as kelvin and is denoted by the letter, k.

Law about Gas. There are certain laws about gas. Some of them are defined here.

Boyle's law. States that the volume of a given mass of any gas at constant temperature varies inversely with pressure i.e.

$$V \propto \frac{1}{p} \quad \text{or} \quad PV = k$$

(k is a constant at a constant temperature and for a constant amount of a gas) *or*

$$P_1 V_1 = P_2 V_2$$

where P_1 V_1 are original pressure and volume of the gas and P_2 V_2 are new pressure and volume of a gas.

A graph between volume-pressure for a gas is a curved line verifies Boyle's Law.

If pressure is straight line then the following graph defines Boyle's law.

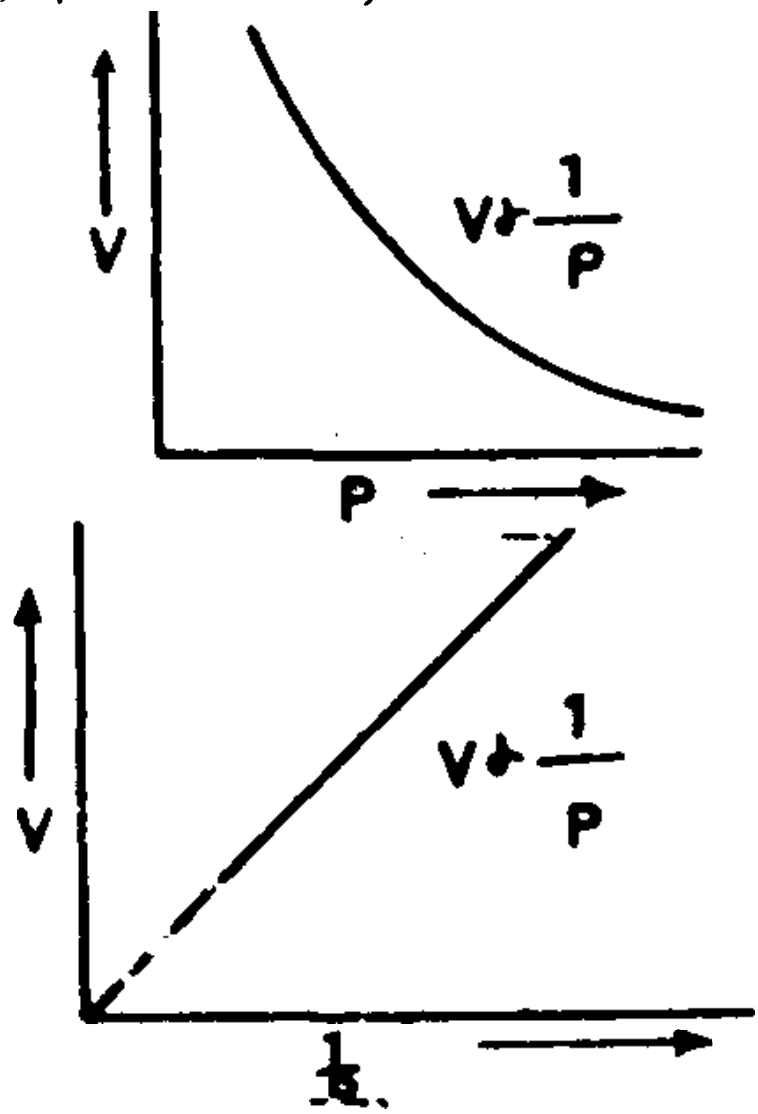


Fig.

Charles' law. The volume of a given mass of a gas at constant pressure is directly proportional to its absolute temperature i.e.

$V \propto T$ (mass and pressure constant)

V = a constant $\times T$; $\frac{V}{T}$ = a *constant.*

$\frac{V}{T} = k$ (where k is a constant)

Pressure-temperature law. The pressure of a sample of a gas of fixed volume is always directly proportional to the temperature on kelvin scale

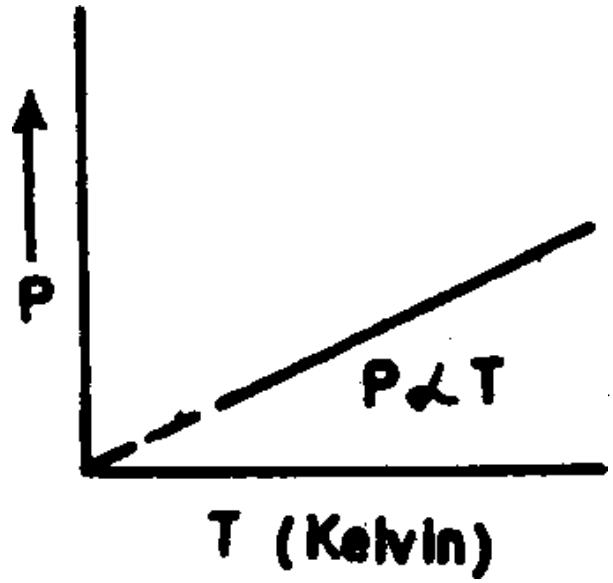


Fig.

i.e. $P \propto T$ or $P =$ a constant $\times T$

or $\frac{P}{T} = k$ (where k is a constant for a given amount of gas at constant volume)

or $$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

Combined gas law. If we combine both the law, Boyle's law and Charle's law then from Boyles Law $V \propto \frac{1}{P}$,

From Charles Law $V \propto T$, so $V \propto \frac{T}{P}$ or $V =$ a constant $\times \frac{T}{P}$ or $\frac{P \times V}{T} =$ a constant.

In general $\frac{P \times V}{T} = k$. The numerical value of k depends on the amount of gas but is independent of nature of gas.

Special form of combined gas law.

$$\frac{P_1 \times V_1}{T_1} = \frac{P_2 \times V_2}{T_2}$$

where P_1, V_1, T_1 are original gas pressure,

volume and temperature and P_2, V_2, T_2 are new pressure, volume and temperature of gas.

Standard Temperature and Pressure (S.T.P.) are—

Standard temperature = 0° C or 273 k

Standard Pressure = 760 mm of mercury of 1 atmosphere.

Avogadro's Law. States that equal volumes of all the gases at the same temperature and pressure contain an equal number of molecules. Avogadro's Law is used to (i) determine the molecular mass of gases, (ii) determine the atomicity of gases.

General Gas Equation. The general gas equation or ideal gas equation can be derived from all the three laws i.e. Boyle's Law, Charle's law and Avogadro's Law is—

$$P \times V = n \times R \times T$$

where P = Pressure of the gas

V = volume of gas

n = Moles of the gas (It represents the amount of gas)

R = Molar gas constant

T = Temperature of the gas.

Gas constant (R). The value of R in different units is as follows:

$R = 0{\cdot}0821$ litre atmosphere per degree kelvin per mole

$R = 8{\cdot}314\ \text{Nm K}^{-1}\ \text{mol}^{-1}$

$R = 8{\cdot}314\ \text{Jk}^{-1}\ \text{mol}^{-1}$

$R = 8{\cdot}314 \times 10^{7}\ \text{ergs K}^{-1}\ \text{mol}^{-1}$

$R = 1{\cdot}987\ \text{calories k}^{-1}\ \text{mol}^{-1}$.

SUBSTANCES (SEPARATION AND PURIFICATION)

All the mixtures containing two solid substances can be separated by any one of the following methods:

By sublimation

By using suitable solvent

By using a magnet.

By Sublimation. The change of a solid directly into vapour on heating and of the vapour on cooling into solid is known as sublimation.

Ammonium chloride, naphthalene iodine, camphor, sublime on heating and can

be recovered in the form of a sublimate by cooling vapours.

By using a suitable solvent. In many cases one constituent of a mixture is soluble in a particular liquid solvent but the other constituent is insoluble in it.

This difference in the solubilities of the constituents of a mixture helps to separate them.

To separate a mixture of sugar and sand, sugar is soluble in water whereas sand is not. The sugar solution in water poured over a filter paper kept in a funnel.

Sand remains as residue on filter paper.

Then the sugar solution is evaporated to have sugar crystal.

By using a magnet. If a mixture contains iron filings as one of the constituents, it can be separated by using a magnet.

A mixture of iron powder and sulphur powder can also be separated by using a magnet. Iron is attracted by a magnet.

Mixtures of a solid and a liquid. All mixtures containing a solid and a liquid can be separated by one of the following methods. (1) By Filteration (2) By Evaporation (3) By Distillation

(1) **Filteration.** Filteration is the process of removal of insoluble substance from a liquid. For example when the mixture of chalk and water is poured on the filter paper kept in a funnel, chalk particles remain as a residue on the filter paper and clear water is obtained as filtrate.

The precipitates formed in a chemical reaction are also separated by filteration.

(2) **Evaporation.** This method is used for recovering dissolved solid substances from liquid mixtures for example salt, can be recovered from a salt-water mixture by the process of evaporation.

When solution is evaporated, water is eliminated and salt is left behind. Copper sulphate, potash alum, potassium nitrate etc. can also be recovered from their aqueous solution by this process of evaporation.

(3) **Distillation.** Distillation is the process of heating a liquid to form vapours and then cooling the vapour to get back the liquid.

For example a mixture of common salt and water mixture is taken in the distillation flask and heated. On heating water forms (steam) which rises up and comes out into the water condenser. Cold water is circulated through the outer tube for cooling purpose.

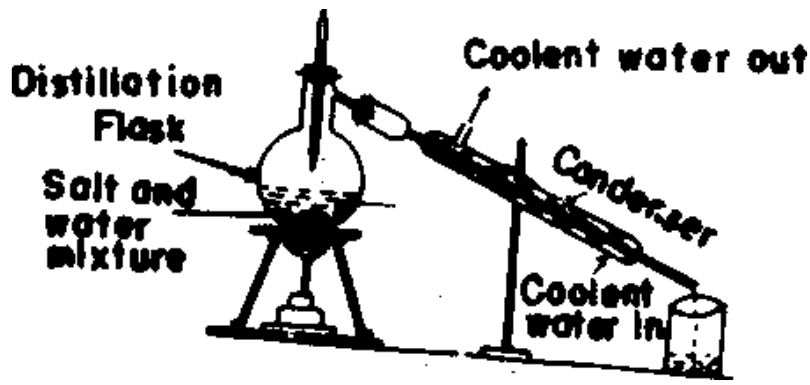


Fig.

Water vapours get cooled in the condenser and give us pure water.

Mixture of two liquids. All the mixtures containing two (or more) liquids can be separated by one of the following processes:

(1) By fractional distillation

(2) By using a separating funnel.

Fractional Distillation. The process of simple distillation is useful only when the

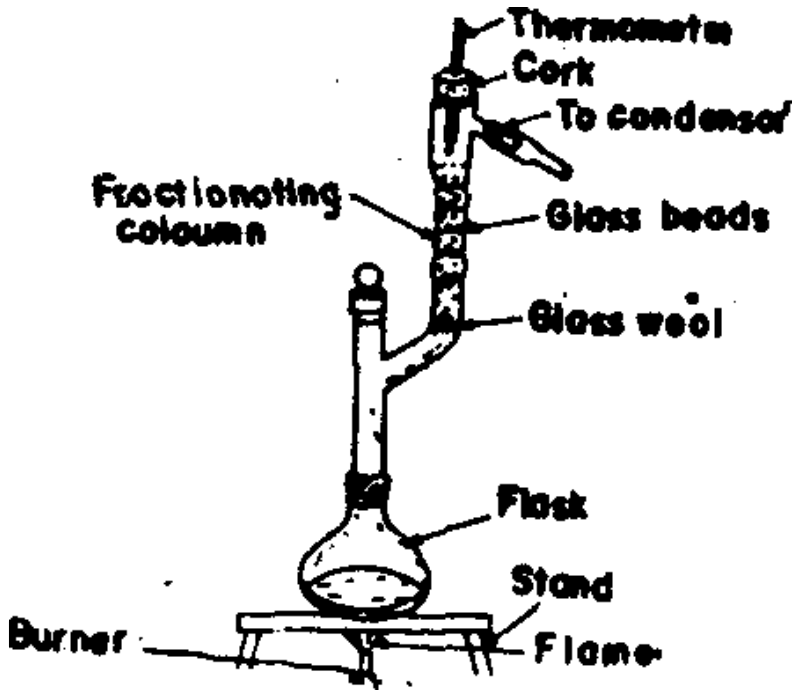


Fig.

boiling points are far apart. When mixtures of substances having narrow range of temperature are to be separated, then technique of fractional distillation as shown if Fig.

This process is very useful for separation of petroleum products like petrol, kerosene oil, diesel, gasoline, coaltar etc.

By separating funnel. The separation of two immiscible liquids by a separating funnel

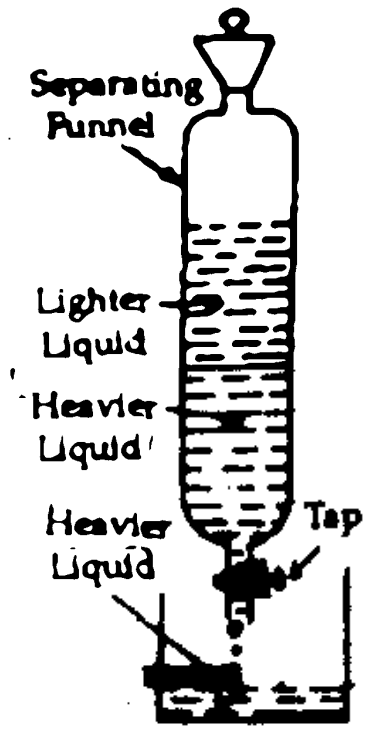


Fig.

is based on the difference in their densities. A mixture of water and kerosene oil can be separated by using a separating funnel.

Solution. A homogeneous mixture of two or more substances in which the dissolved substances is dispersed as particles of molecular dimension (of size $< 10\ A^0$ *i.e.*, 10^{-7} cm) is defined as molecular or true solution *e.g.*, solution of sugar in water.

Suspension. If a heterogeneous system containing large dispersed particles of size greater than 10^{-5} cm remain suspended in the medium, then it is called suspension. But in this case the particles can be seen by naked eye and can be separated by simple filteration.

Colloidal solution. A colloidal solution is a heterogeneous system in which the size of the dispersed particles is between 10^{-5} cm and 10^{-7} cm *e.g.* soap and detergent soap solution.

Crystallization. Regular arrangement of atoms in a fixed geometric pattern is known as a crystal. Crystallization is the

phenomenon of arrangement of atoms in a regular geometrical pattern, when it is allowed to solidify. Alum forms eight sided or octahedral crystals, whereas, copper sulphate forms rhombohedral crystals.

Sublimation. Certain substances change directly from solid to vapour on heating or *vice versa* on cooling. Naphthalene and camphor sublimate on heating. This process is known as sublimation. Such substances can be separated from other substances on heating. Fig. shows sublimation process.

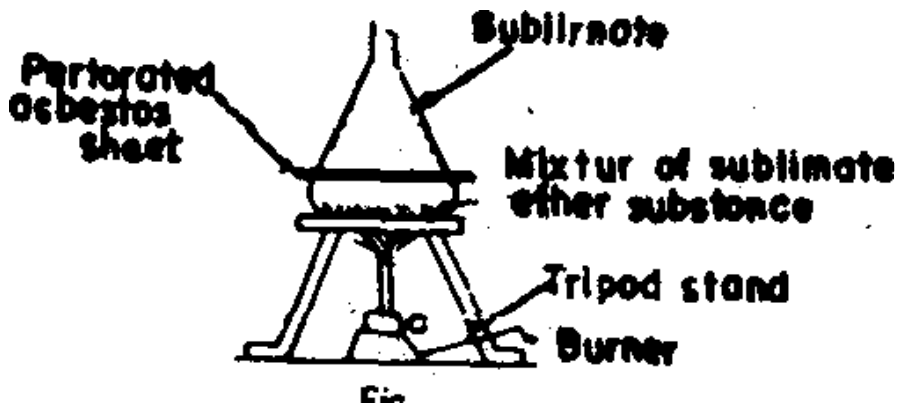


Fig.

Pure substance. Pure substances are those matters which have definite invariable composition and properties like melting point, boiling point etc.

Purity of a solid. The purity of a solid substance can be tested by determining its melting point.

Purity of a liquid. The purity of a liquid can be checked by determining its boiling point.

Fusion. A process in which solid changes to liquid.

Liquification. It is the process which involves the change of a gas into the liquid state.

Solidification. It is the process which involves the change from liquid to solid state.

CHEMICAL BONDING

Cathode Rays. When a high potential difference of 20,000 volts is applied across a gas taken in a discharge tube at low pressure of about 0.001 torr, then some radiations are emitted from the cathode. These move towards the anode. These rays are called *cathode rays* because they emanate from the cathode as shown in figure.

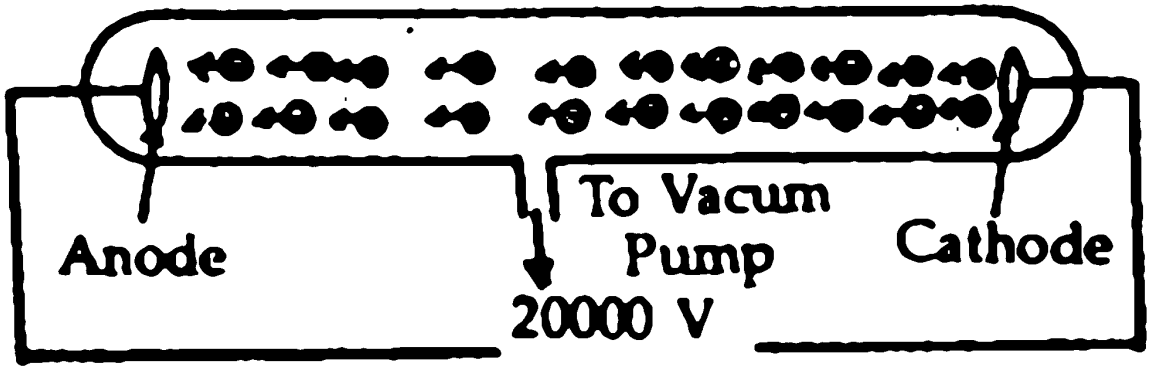


Fig.

Properties of Cathode rays

(1) The cathode rays are constituted by fast moving electrons.

(2) They travel in a straight line.

(3) They possess mechanical energy.

(4) They produce heat when focussed on any metal.

(5) They ionise the gas when they pass through it.

(6) They are deflected by electric and magnetic field.

(7) They affect the photographic plate.

(8) They produce flourescence when focussed on metals.

Anode or positive rays. In a discharge tube, if the cathode used in perforated and high voltage is supplied between the electrodes, when the pressure within the tube is below 0.001 mm Hg, then new type of rays come through the perforation in the cathode.

Since these rays come through perforation in the cathode, are called anode rays as

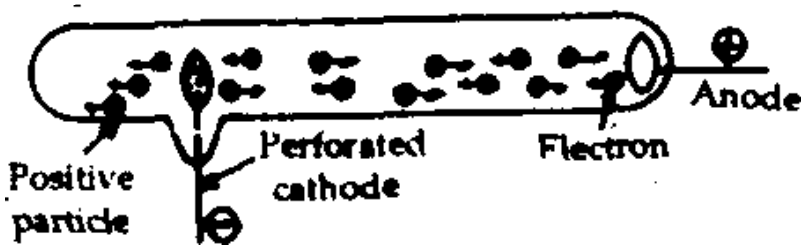


Fig.

they move from the anode side through the gas.

In a discharge tube, when the gas atoms lose electrons, they acquire a positive charge and move away from the anode.

Properties of anode rays

1 Anode rays travel in a straight line.

2 Anode rays can produce mechanical effects.

3 Anode rays are positively charged.

4 The nature of anode rays depends on the gas of a discharge tube.

5 The mass of anode rays particle is almost equal to the mass of the atom from which it is formed

Neutron. Neutron is a neutral particle found in the nucleus of an atom.

Atoms of all the elements contain neutron except hydrogen atom which does not contain neutron. The relative mass of a neutron is 1 *a.m.u.* and has no charge.

Rutherford's experiment. Rutherford bombarded a-particles on thin gold foil as shown in Fig. He observed that most of the α-particles passed through the gold foil undeviated while a few were deflected in various directions.

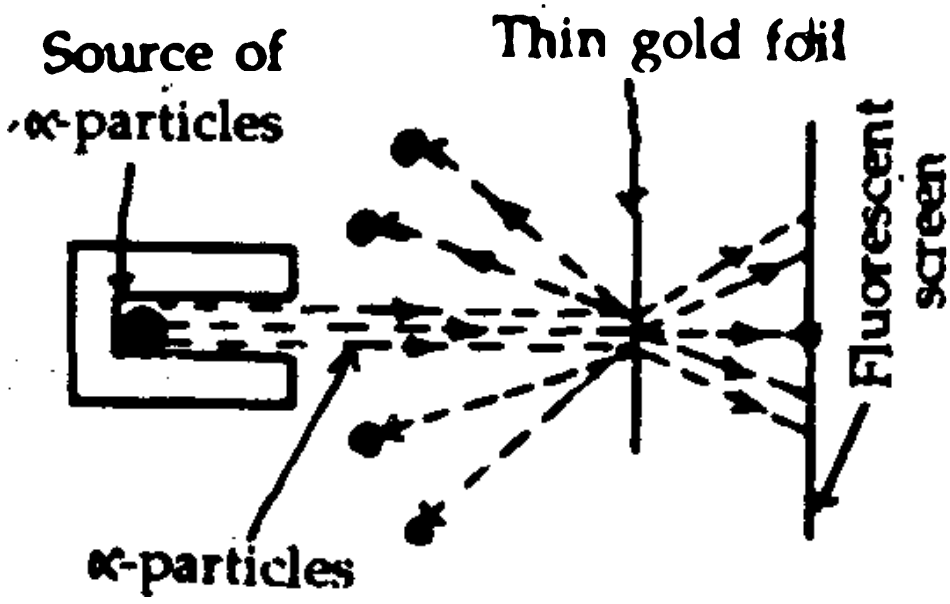


Fig.

He concluded that deflection of α -particles was due to heavy central portion of the atom having positive charge. On the basis of his experiments Rutherford gave the following postulates.

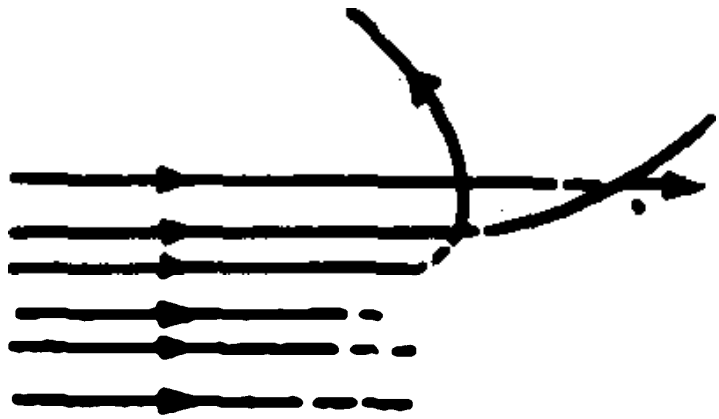


Fig.

(A) An atom consists of a massive nucleus surrounded by a number of electrons revolving in orbits.

(B) The force of attraction between the nucleus and the electron is balanced by the centrifugal force of an electron.

The two deficiencies of this model are-

(i) It is possible to have infinite number of orbits. In practice it is not the case.

(ii) The electron must continuously lose energy and fall into the nucleus. Actually it is not the case.

Bohr's concept of an Atom

(A) Atom consists of a heavy positively charged nucleus. The whole mass of an atom is concentrated in the nucleus.

(B) The electrons in an atom revolve around the nucleus in definite circular paths called orbits or energy levels.

(C) Each energy level is associated with definite amount of energy

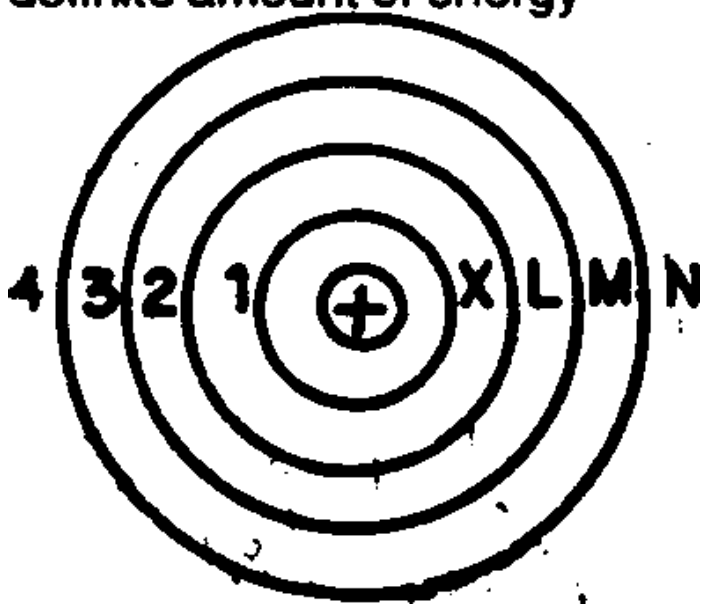


Fig.

(D) The change in energy takes place when electron jumps from one energy level to another energy level

Distribution of electrons in an Atom. Bohr gave the following suggestions for distribution of electrons in an atom.

(1) The maximum number of electrons in an orbit (shell) is equal to $2n^2$.

The first orbit cannot have more than $2 \times 1^2 = 2$ electrons.

The second orbit cannot have more than $2 \times 2^2 = 8$ electrons.

The third orbit cannot have more than $2 \times 3^2 = 18$ electrons.

The fourth orbit cannot have more than $2 \times 4^2 = 32$ electrons.

(2) The outermost orbit cannot have more than 8 electrons.

(3) The penultimate (last but one) orbit cannot have more than 18 electrons.

(4) The per-penultimate (last but two) orbit cannot have more than 32 electrons.

(5) No orbit can have more than 32 electrons.

Mass number. The total number of protons and neutrons present in one atom of an element is known as its mass number.

Mass number = no. of protons + no. of neutrons.

Isotopes. The atoms of some elements possess the same atomic number but different atomic masses. Such atoms are known as isotopes of an element. Isotopes possess similar chemical properties but different physical properties. The three isotopes of hydrogen are protium, deuterium and tritium.

Valence Electrons. The number of electrons present in the outermost orbit of an atom are known as valence electrons.

Valency. The valence of an element is defined as the combining capacity with other elements. Alternatively, the valence of an element is said as the number of electrons it can lose, borrow or share with another ele-

ment. It is never greater than 7. The outermost electronic configuration is responsible for the variability of the valency.

X-rays. X-rays were discovered by W. K. Rontgen. He found that, when cathode rays strike the wall of a heavier metal, new kind of rays are emitted.

These rays are not affected by electric and magnetic field, but can pass through opaque materials. He named these rays as X-rays.

Radioactivity. Henry Bacqueral discovered radioactivity. It is the phenomenon of continuous emission of α -particles, β -particles and γ-particles by radioactive substance.

The elements that emit radioactivity are Uranium, Radium, Thorium and Polonium.

Alpha (α) Particles. Alpha particles possess four units of mass and +2 units of charge. The other properties of α -particles are

(1) They have +ive charge of +2 units

(2) They travel with a velocity of 3×10^7 m/s *i.e.* $\frac{1}{10}$ the speed of light.

(3) They are lesser penetrating. These rays are stopped by aluminium foil of 0.01 mm thickness.

(4) Alpha particles possess strong ionising power *i.e.* they take out electrons from the gas through which they pass.

(5) Alpha particles darken the photographic plate.

Beta (β) -Particles. Beta rays possess the following properties.

(1) β -particles possess feeble (negligible) ionising power.

(2) It possesses negligible mass.

(3) The velocity of β -particles is equal to velocity of light *i.e.* 3×10^8 m/s.

(4) The penetrating power of β -particles is 100 times more than that of α -particles.

(5) Beta rays are negatively charged rays. The charge on a beta particle is equal to that of an electron.

(6) β -particles affect the photographic films rapidly.

Gamma (γ) -Particles. Gamma particles possess the following properties.

(1) They are electromagnetic waves. They are not regarded as particles.
(2) They possess very high penetrating power.
(3) They travel with the velocity of light *i.e.* 3×10^8 m/s.
(4) Gamma particles are neutral in nature *i.e.* they do not posses any charge.
(5) They do not ionise the material through which they pass.
(6) Gamma particles darken the photographic plates rapidly.

Properties of X-rays

(1) X-rays consist of electromagnetic waves of very short wave length.

(2) Like light, X-rays show reflection, refraction, interference and diffraction.

(3) They ionise the gas through many which they pass.

(4) They possess high penetrating power and can pass through many solids.

(5) They have a destructive effect on living tissues.

(6) **Use of X-rays**

Industrial applications

(i) to detect defects in components and crystals.

(ii) to analyse the structure of alloys.

(iii) to study the structure of rubber and plastics.

Medical applications

(i) to detect fractures, tumours and foreign materials present in the body.

(ii) many types of skin diseases and tumours can be cured by X-rays.

(iii) for identification of different types of cells and tissues

Scientific applications

(i) for investigating the structure of atom.

(ii) for identification of chemical elements including determination of their atomic number.

(iii) to analyse the structure of complex organic molecules.

Chemical Bonding: When a group of atoms remain together by forming a stable combination having characteristic properties, it is known as a molecule.

Anion. When atom gains one or more electrons, it becomes negatively charged and is known as anion. e.g. F^-, O^{2-}, S^{2-} etc.

Cation. On losing one or more electrons, an atom acquires, positive charge and is known as cation. e.g. Li^+, Be^{++}, Cu^+, Au^{3+} etc.

Ions. An atom or molecule that carries a positive or negative charge because of loss or gain of electrons. It is said to be anion.

Noble gases. Noble gases exist as mono-atomic molecules. These do not form compounds either among themselves or with other elements. They are chemically inert. These are: Neon (Ne), Helium (He), Argon (Ar), Krypton (Ke), Xenon (Xe), Radon (Rn).

Inertness of noble gases. The noble gases have 8 electrons in their valence (outermost) shell (except helium which has 2 electrons). They have stable electronic configuration. And can neither lose electrons nor can gain electron.

Their ionization energy is very high. This is the reason that they are inert in their behaviour.

Chemical bond. The attractive force which holds together the constituent atoms in a molecules is known as a chemical bond.

Types of bonds. There are 3 types of bonds (i) Electrovalent bond (ii) Covalent bond (iii) Co-ordination bond.

Electrovalent bond. The chemical bond formed by the transfer of electrons from one

atom to another is known as an electrovalent bond or ionic bond. Take the example of sodium chloride (NaCl), when sodium and chlorine atoms approach each other, sodium (2, 8, 1) donates one electron to form Na^+ (2, 8) which has an electronic configuration identical with nearest noble gas neon (2, 8).

The chlorine atom (2, 8, 7) take up the electron and becomes Cl^- (2, 8, 8) which has electronic configuration similar to that of argon. Two oppositely charged ions (Na^+ and Cl^-) are held together by electrostatic force of attraction acting between them as shown here

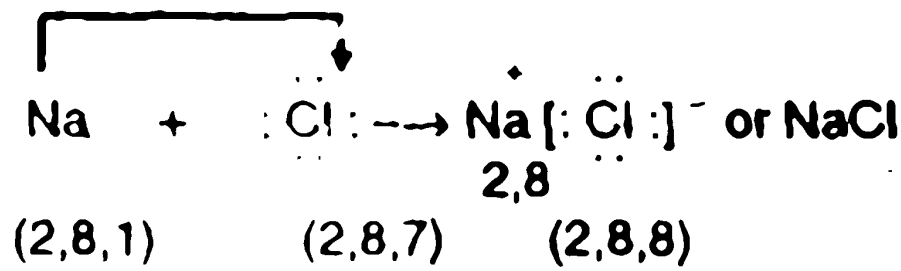
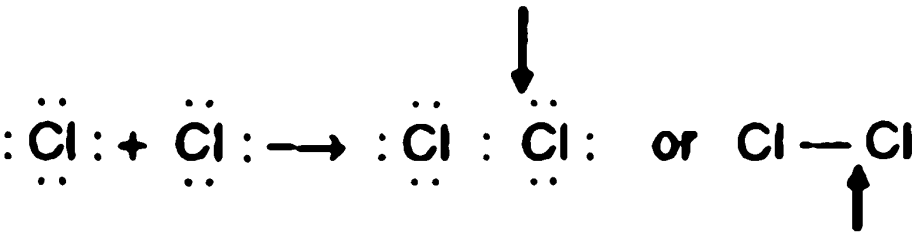


Fig.

Hence, when a metal reacts with a non metal, transfer of electrons takes place from metals atoms to the non-metal atoms and an electrovalent (or ionic bond) is formed.

Covalent bonds. The chemical bond formed by sharing the electrons between two atoms is called covalent bond. These bonds are of three types—

Single covalent bond. A single covalent bond is formed by the sharing of one pair of electrons between two atoms. The example of single covalent bonds is the formation of chlorine molecules. Two chlorine atoms share one electrons each and acquire stable electronic configuration as shown below



(2,8,7) 2,8,7) Chlorine molecule Single bound

(2,8,8) (2,8,8)

Fig.

In general we can say that whenever two atoms of the same element combine to form a molecule, a covalent bond is formed.

Double bond. The bond between two

atoms formed by sharing of two pairs of electrons is called a double bond. Two horizontal lines between the two atoms denote a double bond e.g, O = O.

The formation of oxygen molecule, O_2 is an example of double bond. Oxygen atom has six electrons in its outermost shell, two short of forming a complete octet (8). Thus each oxygen atom in O_2 shares 2 electrons with the other oxygen atom and attains stable configuration as shown

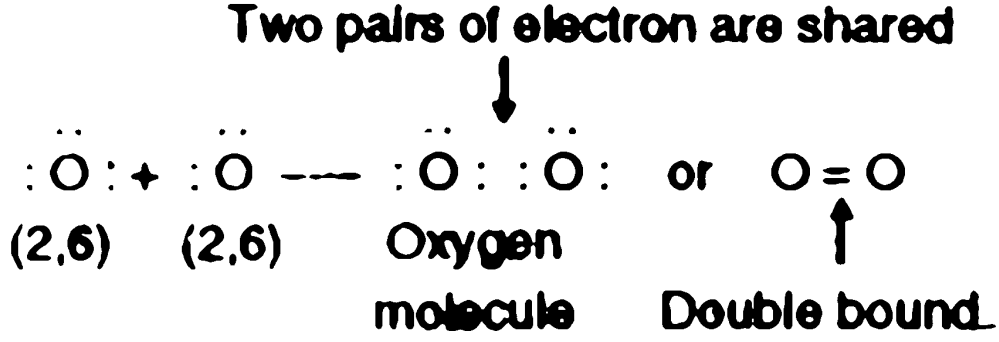


Fig.

Triple bond. The bond formed between two atoms through the sharing of three electron pairs is called a triple bond. Three horizontal lines between two atoms denote a triple bond. The formation of nitrogen molecule, N_2 is an example of triple bond.

Nitrogen atoms have five electrons in their outermost shell. Therefore in N_2 molecules, two nitrogen atoms share 3 electrons with each thus acquiring the stable structure and forming an N_2 molecule with triple bond:

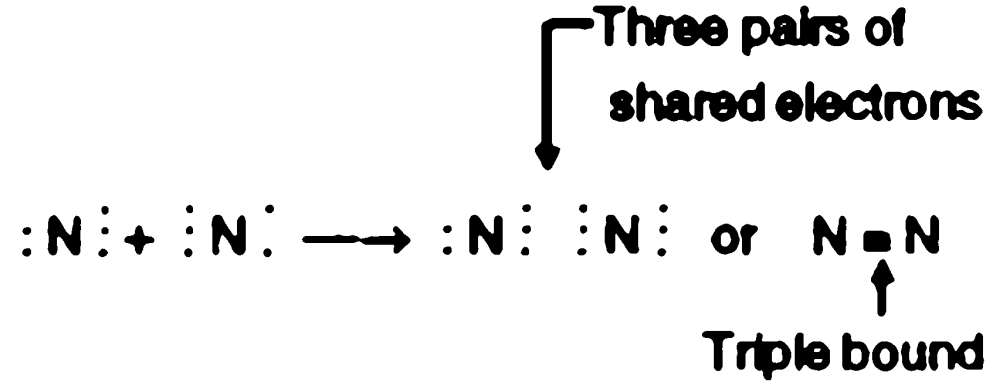


Fig.

Polar and Non-polar covalent bonds. A non-polar bond is formed by sharing of electrons between similar atoms *e.g.*, bonds in Cl_2, O_2 and H_2.

A polar bond is formed where the combining atoms sharing a pair or electrons are dissimilar. In this case the two atoms acquire a partial positive and negative charge, the magnitude of charge depends on the difference in the affinities for electrons of the

two atoms.

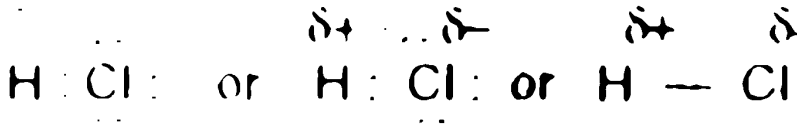
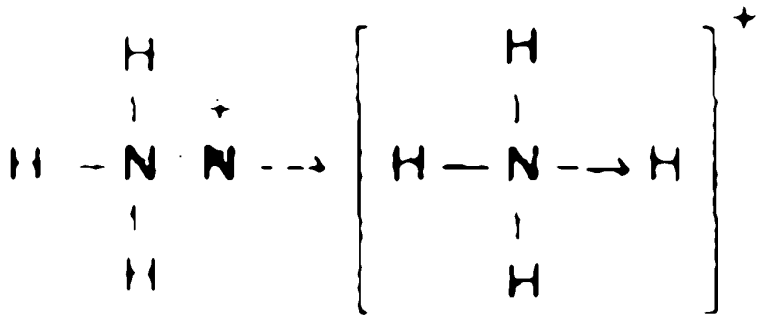


Fig.

The hydrogen chloride molecule. The covalent bond is polar.

Coordinate bond: This type of bond is formed by unequal sharing of electron pair. One of the participating atoms provides both the electrons (electron pair or lone pair) and this is shared by both the atoms. The atom that provides lone pair is known as donor and the other atom is known as acceptor. This bond is represented with an arrow pointing from donor to acceptor. e.g NH_4^+



Dalton's Atomic Theory. Dalton gave the following postulates of an atom.

(A) Each element is composed of small particles called atoms.

(B) Atoms of a particular element are all alike i.e. different elements possess different kinds of atoms

(C) Atoms can neither be created nor destroyed. In a chemical reaction, redistribution of atoms takes place.

(D) In a given compound the relative number of atoms is fixed.

Quantity	*Definition*	*SI Unit*
Area	length × length	m^2
Volume	length cube	m^3
Power	Rate of doing work	J/s (Watt = W)
Speed	distance travelled in unit time	m/s
Acceleration	Rate of change of velocity	m/s^2

Pressure	force per unit area	kgm/s^2 (Pascal = P)
Energy	Force time distance travelled	N (Joule = J)
Force	mass × acceleration	kgm/s^2 or N
Density	mass per unit volume	kg/m^3

Electronic distribution of elements. Atomic mass and atomic number of elements are written as ${}^{a}X_{b}$ where *a* is the atomic mass of element X. The atomic number of the element X is *b*.

${}^{23}Na_{11}$ means an atom of sodium possesses eleven protons. Atomic mass of sodium is 23 and its atomic number is 11.

Stability of Inert Gases. Except Inert gases possess eight electrons helium in their outermost orbit since their outermost orbit is saturated, they do not lend, borrow or share

electrons easily. Gases like helium, neon, argon, krypton and xenon are termed as inactive or inert gases.

Ion. Electrically charged atom or group of atoms is called an ion. An ion is formed when an atom gains or loses electron/electrons. The atoms and ions possess different properties.

Cation. Cation is formed when an atom loses one or more electrons. When a sodium atom loses one electron, it becomes a cation of sodium

Na -	$1e$	Na^+
	$\rightarrow$	
Sodium atom		Sodium cation
K	$-1e$	K^+
	$\rightarrow$	
Potassium atom		Potassium cation

Anion. A negatively charged atom or ion is called an anion. When an atom gains one electron it becomes an anion.

Cl	$-1e$	Cl
	$\rightarrow$	
Chlorine atom		Chlorine ion

Sl. No.	*Atom*	*Ion*
1.	It is electrically neutral.	It is electrically charged. The charge is positive or negative.
2.	It is not very stable	It is stable.
3.	Number of protons and electrons are equal.	Number of protons and electrons are different.

Ionic Bond. Also known as electrovalent bond. This bond is formed by the transfer of electrons from one atom to another atom. It takes place between two oppositely charged ions. Sodium and Chlorine combination to form sodium chloride is an excellent example of ionic bond.

Na	Cl	→	Na	Cl
2, 8, 1	2, 8, 7		2, 8	2, 8, 8
Sodium atom	Chlorine atom		Neon config-uration	Argon con-figuration

Bonding Pair. The formation of a bond by sharing of electrons is known as bonding pair.

Characteristics of Ionic compounds

(1) Ionic compounds are generally solid and crystalline in nature.

(2) Ionic compounds have high melting point.

(3) Ionic compounds conduct electricity in the molten state.

(4) Ionic compounds are soluble in water.

Characteristics of Covalent Compounds

(1) Covalent bond is formed by sharing of electrons.

(2) Covalent molecules generally exist in gaseous form.

(3) Covalent molecules have low melting and boiling points.

(4) Covalent compounds are generally poor conductors of electricity.

(5) Covalent compounds are generally insoluble in water.

Duplet. The tendency of an atom to have two electrons in the outermost or valence shell is called as duplet. Atom of helium is a duplet.

Octet Rule. The tendency of an atom to have eight electrons in the outermost orbit is called an octet. It is a noble gas configuration. Ne, Ar, Kr, Xe and Rn possess eight electrons in the outermost orbits.

The electronic distribution of noble gases is shown here in table.

Element	*Atomic number*	*Electronic distribution*
He	2	2
Ne	10	2, 8
Xe	54	2, 8, 18, 18, 8
Rn	86	2, 8, 18, 32, 18, 8
Ar	18	2, 8, 8
Kr	36	2, 8, 18, 8

Structure of Sodium Chloride. It is also known as common salt. The distribution of sodium chloride atoms in its crystalline structure is shown in Fig.

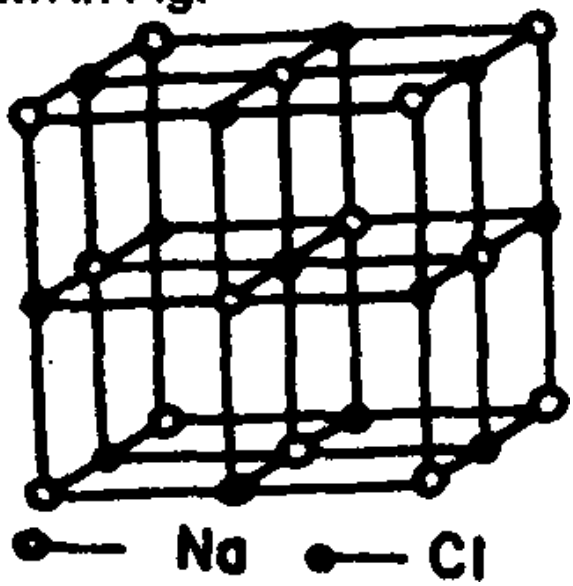


Fig.

Difference between Ionic Bond and Covalent Bond

S.No.	*Ionic Bond*	*Covalent Bond*
1.	Solid compounds are formed.	Generally gaseous compounds/ molecules are formed.
2.	Density is high.	Density is low.

3.	High melting points.	Low melting points.
4.	Good conductors of electricity in molten or dissolved state.	Poor conductors of electricity.
5.	Bond is formed by electrostatic forces of attraction.	Bond is formed by sharing of electrons.

Bonds in Inert Gases. Inert Gases like helium and argon possess fully saturated outermost shall with electronic configuration as shown here.

Element	*At.No.*	*Electronic Configuration*
Helium.	2	$1s^2$
Argon	18	$1s^2, 2s^2, 2P^6, 3s^2, 3P^6$

These gases possess limited attraction due to fully saturated outermost shell. The bond between molecules of these gases is

too weak due to dispersion type secondary bond. Hence inert gases show very limited attraction with each other.

Ionization Energy. Ionization energy (IE) is a energy required to remove an electron from a free gaseous atom. It is the most fundamental property of an atom that controls electron distribution. Here is the example of sodium atom.

When an electron is removed from natural sodium, a positively charged ion is left behind.

$$Na + \text{energy} \rightarrow Na^{+} + e^{-}$$

Ionization energy of sodium is 495 kJ mol^{-1}.

Ionization energy decreases down in a group. This is due to the reason, that in a group, the outermost electron is farther most from the nucleus and hence less energy is required to remove it. Cesium possesses the lowest amount of ionization energy (3.87 esu).

Metallic Bond. Atoms in metallic crys-

tals are bound together by metallic bonds. The valency electrons in a metal are not held, strongly because metals have very small number of valency electrons. The forces in metallic bonds are electrostatic in origin. They can be easily released to the common pool due to weak binding force. The atomic orbitals, holding the valence electrons are assumed to merge to produce a delocalised orbital system throughout, on which the electrons are free to move and this permeates the whole metal.

Characteristics of a Metallic Bond. J. D. Bernal suggested the following characteristics of a metallic bond.

1. Ability to act between identical metallic atoms, and at the same time between widely different metallic atoms.
2. Lack of direction, as shown by the Positive retention of properties in the liquid state, and of saturation to permit large number of close neighbours

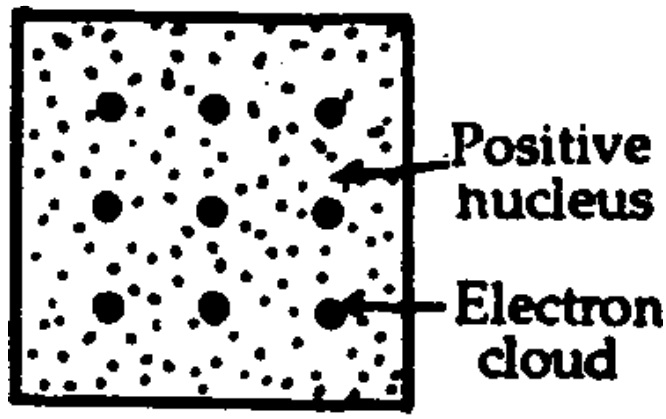


Fig.

3. Attractive force varies inversely as some high power of inter atomic distance.
4. Ability to permit electron transfer from one atom to another atom.
5. Equilibrium repulsive force, which is atomic in nature.

Hydrogen Bond. The small nucleus of Hydrogen containing one proton is attracted by the unshared electrons of the neighbouring O_2 molecule. These forces of attraction provide a bond between two molecules and is a special case of polarisation.

Sigma bond. Such a bond is formed by the axial overlap of two orbitals belonging to different atoms. It is formed by axial overlapping or s-s, p-p, s-p orbitals. It is denoted by σ

π - **bond.** Such a bond is formed by side ways over lapping of atomic orbitals of different atoms.

A single bond is always a σ -bond. A double bond contains 1 σ - and 1 π -bond and a triple bond consists of 1 σ - and 2 π - bonds.

Bond Energy. It is the energy required to break a bond and to separate bonded atoms.

Bond length. It is the distance between the nuclei of bonded atoms. Bond length r of different molecules is as follows

H - Cl = 136 pm

H - H = 74 pm

Cl - Cl = 198 pm

Comparison between various Types of Bonds

Property	*Ionic bonds*	*Covalent Bonds*	*Metallic Bonds*
Bonding Force	Electro-static force between +ive and -ive is	Electro-static force between alternately oppositely charged outer shells of two atoms	Electro-static force between -ve electron cloud and +ve ions
Appro-ximate range of bond action (pm)	200-300	110-200	—

Character of Bond	Non-directional	Directional	Non-directional
Bond formation condition	One of the atoms has small number of valence electrons.	Atomic orbitals of two atoms overlap	For elements having small number of valence electrons.
Conductivity	Low	Low	Good
Hardness	High	Low	High
Density	Intermediate	Intermediate	High
Melting point	Low	High (if any)	High

CLASSIFICATION OF ELEMENTS

Element. An element is a substance which can not be split up into two or more simpler substances by usual chemical methods of applying heat, light or electric energy. An element is made up of atoms.

Example of elements. Hydrogen, Oxygen, Sodium, Magnesium, Iron, Nickel, Gold, Silver etc.

Elements have been divided into metals and non-metals. All metals are solids except Mercury which is a liquid.

Hydrogen, Oxygen, Nitrogen are some of non-metallic elements. All the non-metals are solids or gasses except Bromine which is a liquid.

Atomic mass of an Element. The atomic mass of an element is numerical number which indicates how many times an atom of an element is heavier than 1/12 mass of Carbon-12 atom For example the atomic mass of Magnesium is 24 which indicates that one atom of Magnesium is 24 times heavier than 1/12 of a Carbon-12 atom. The atomic mass unit (a.m.u) and atomic weight unit are just the same.

Classification of elements. Scientists have tried a number of ways to arrange the elements in pera and group having similar properties and there are 106 elements and each elements forms a large number of compounds In order that working knowledge of chemistry (i.e., that of elements and compounds) is readily available it is necessary that elements are classified based on their properties. In 1815 Prouts suggested that all the element are made up of hydrogen atom hence they are related to each other through their atomic masses.

(ii) **Dobereiner's Triads.** In 1817

Dobereiner found that when elements are arranged in the order of increasing atomic masses, groups of three elements (known as triads) having similar chemical properties are obtained. He said that the properties of Lithium sodium and potassium with atomic mass 7.23 and 39 respectively are similar. He said that the atomic mass of sodium is the mean of atomic masses of lithium and potassium.

$$\text{Atomic mass of sodium} = \frac{7 + 39}{2} = 23$$

This classification of elements failed because it could not cover all the then known elements.

Newland's Law of Octaves. In 1865 Newland found that when elements are arranged according to increasing atomic masses, the properties of the eighth elements (starting from a given one) are repetition of the properties of the first elements.

Li	Be	B	C	N	O	F
7	9	11	12	14	16	A

Na	Mg	Al	Si	P	S	Cl
23	24	27	28	31	32	35
K	Ca					
39	40					

If we start from lithium (Li) we find that the eighth elements from it is sodium (Na). So according to Newland the properties of eighth element, sodium should be similar to that of lithium

(iv) **Lothar Meyer's classification.** In 1869 Lothar Meyer a German Scientist suggested that when the atomic volumes (Mass + density) are plotted against the atomic masses of various elements, the elements occupying similar positions (either peak or trough) should have similar properties. He arranged the elements in order of their increasing atomic weights. Meyer's table was based on physical properties like atomic volume, melting point and boiling point of elements. In the same year, Dmitri I. Mendeleev, a Russian scientist prepared inde-

pendently, his table of elements. Mendeleev's system was more elaborate. His system of classification was based on wider range of physical and chemical properties and is more useful for study of behaviour of elements.

Periodic Table. It is chart of elements prepared in such a way that the elements having similar properties occur in the same vertical column or group. It is called periodic because the elements having similar properties occur after certain intervals or periods and it is called table because elements are arranged in a tabular form.

Mendeleev's classification. Mendeleev said that properties of elements are periodic functions of atomic masses. Much of Mendeleev's assumptions were based on the similarities in the formulae of compounds formed by the elements, Mendeleev stated his periodic law. "The properties of the elements, as well as the formulae and properties of their compounds depend in a periodic manner of the atomic weight of the ele-

ments." A table of elements in which elements with similar properties are placed together is known as a PERIODIC TABLE.

(i) The table of divided vertically into 8 columns known as groups and horizontally into rows known as periods.

(ii) Each group of the table is further sub-divided into two sub-groups A and B. The resemblances of the properties of the elements within a sub-group one more marked than those between the members of the two subgroups.

While devising his periodic table, Mendeleev realised that some of the elements do not fit properly in the scheme of classification of elements on the basis of their atomic weight. He observed that many elements with similar properties were missing in his periodic table.

He predicted the properties of those missing elements on the basis of the properties of other elements in the same group.

Metals gallium and germanium were not known at the time when Mendeleev proposed his periodic table. Mendeleev named those elements as EKAALUMINIUM and EKASILICON, because he believed that these elements were similar to aluminium and silicon in properties. These elements were discovered later. It is interesting to point here that these assumptions proved remarkable correct as per Mendeleev's predictions.

Mendeleev's prediction of the element ekasilicon are shown here in the table.

Property	*Tin and its compounds*	*Silicon and its compounds*	*Mendeleev's predictions for ekasilicon (1871)*	*Winkler's report of germanium (1886).*
Atomic mass	118.7	28.1	72	72.6
Density ($g\ cm^{-3}$)	7.31	2.42	5.5	5.36

Melting Point (K)	505	1683	high	1231
Preparation of the element	Reduction of SnO_4 with carbon	Reduction of K_2SiF_6 with sodium	Reduction of MO_2 or $K_2M_2F_6$ with Na	Reduction of K_2GeF_6 with Na
Action of acid and alkali	Slow attack by conc. HCl; attacked by HNO_3; not attacked by sodium hydroxide	Acid resistant slow attack by alkali	Will be slightly attacked by acid; will not be attacked by alkali.	Not attacked by HCl or dilute NaOH; reacts with hot conc. HNO_3
Oxide formula and density ($g\ cm^{-3}$)	SnO_3 7.0	SiO_2 2.65	MO_2 4.7	GeO_2. 4.7

Sulphide formula and properties	SnS_3, insoluble in water, soluble in ammonium sulphide	SiS_2, decomposes in water	MS_2, insoluble in water; soluble in ammonium sulphide	GeS_2 insoluble in water and dilute acid; soluble in ammonium sulphide
Chloride formula	$SnCl_4$	$SiCl_4$	MCl_4	$GeCl_4$
Boiling point (K)	387	330.6	373	356
Density ($g\ cm^{-3}$)	2.23	1.50	1.9	1.88

Important Feature in Mendeleev's Table

Each group of the table in further subdivided into two subgroups A and B. The elements of each subgroup possess marked similarity in properties. The groups and

periods proposed by Mendeleef are given below

The table consists of 8 vertical rows (groups) and horizontal rows (periods).

Group	I	II	III	IV	V	VI	VII	VIII
General Formula	R_2O	RO	R_2O_3	RH_4	RH_3	RH_2	RH	RO_4
Family	A B	A B	A B	A B	A B	A B	A B	
1.	H							
2.	Li	Ba	B	C	N	O	F	
3.	Na	Mg	Al	Si	P	S	Cl	
4.	K	Ca		T	V	Cr	Mn	Fe, Co, Ni
5.	Cu	Zn			As	Se	Br	
6.	Rb	Sr	Ys?	Zr	Nb	Mo		Ru, Rh, Pd

7. 8.	Ag Cd	Cd Ba	Gn Pd?	Sn Ce?	Sb	Te	I	
9. 10.			Er?	La?	Ta	W		Os, Ir, Pt
11. 12.	Au	Hg	Ti	Pb Th	Bi	u	(apv)	

Mendeleev's Modern Law. According to Mendeleev's modified periodic law. "The properties of the elements are periodic function of their atomic number."

Advantages of Mandeleev's Periodic Table

(i) The division of elements into groups and periods have made their study simply and systematic.

(ii) The properties of elements could be predicted from their position in the periodic table.

(iii) When Mendeleev arranged the elements in the periodic table, 63 elements were known. By arranging the

elements, in the periodic form the properties of unknown elements could be guessed. It helped much in the discovery of new elements.

Defects of the Mendeleev's periodic table

1. The elements of higher atomic mass is placed before the element of lower atomic mass.
2. The position of hydrogen is not properly defined. Hydrogen is placed in IB group, whereas it resembles the elements of Group IA (alkali metals) as well as the elements of group VII A (halogens).
3. No position for isotopes are available, for example two isotopes of chlorine ^{35}Cl and ^{37}Cl should have different place in the table.
4. Some chemically dissimilar elements are placed in the same group. For example the noble metals copper (Cu), silver (Ag) and gold (Au) are

placed in group I along with alkali metals (Li, Na, K, Pb, Cs etc.). Their properties are different.

Table of some important Elements [Based on Carbon-12]

Name	*Symbol*	*Atomic number*	*Atomic weight*
Actinium	Ac	89	(227)
Aluminium	Al	13	26.9815
Arsenic	As	33	74.9216
Barium	Ba	56	137.34
Bismuth	Bi	83	208.980
Bromine	Br	35	79.909
Calcium	Ca	20	40.08
Carbon	C	6	12.01115
Chlorine	Cl	17	35.453
Copper	Cu	29	63.54
Dysprosium	Dy	66	162.50

Europium	Eu	63	151.26
Francium	Fr	87	(223)
Gold	Au	79	196.967
Helium	He	2	4.0026
Hydrogen	H	1	1.00797
Iodine	I	53	126.9044
Iron	Fe	26	55.847
Krypton	Kr	36	83-80
Lead	Pb	82	207.19
Manganese	Mn	25	54.9380
Mercury	Hg	80	200.59
Neptunium	Np	93	(237)
Nickel	Ni	28	58 71
Oxygen	O	8	15.9994
Phos-phorous	P	15	30.9738
Potassium	K	19	39.102

Modern Periodic Law. Mendeleev's periodic classification of elements was based on their atomic masses. It is now realised the atomic number is more fundamental property than atomic masses.

The modern periodic table is based on atomic numbers. It can be stated as, "The physical and chemical properties of elements are the periodic functions of their atomic number."

In 1984 a conference of IUPAC was held. The recommended long form of periodic table as recommended by the conference is shown in Fig.

The horizontal rows of elements in the periodic table are called periods. There are seven periods in the long form of the periodic table and are usually numbered as 1, 2, 3, 4, 5, 6 and 7. The first period consists of 2 elements. The subsequent periods consist of 8, 8, 18, 18 and 32 elements. The seventh period of the table is incomplete.

The two elements of the first period are hydrogen ($1s^1$) and helium ($1s^2$). The first (K)

shell of helium is complete. The second period starts with lithium, which is having one electron in the 2s orbital. The L shell is complete with neon, whose electronic configuration is $1s^2, 2s^2, 2p^6$. There are eight elements in the second period.

The third period consists of 8 elements. The first elements of the group is sodium, while the last element is argon. The fourth period consists of 18 elements. The first element of this period is potassium while the last element is Krypton. The fifth period consists of 32 elements. This period beginning with rubidium is similar to fourth period, but contains second transition series starting with yttrium of atomic number 39. The last element of this period is Xenon. The sixth period contains 32 elements and, successive electrons enter the 6s, 4f, 5d and 6p orbitals in that order. Filling up of the 4f orbital begins with element cerium (atomic number = 58) and ends at letutinium (atomic number = 71). The seventh period is similar to 6th period with filling up of the 7s, 5f, 6d and 7p

orbitals. However, this series is incomplete and includes most of the man made radioactive elements.

The Groups. The vertical columns of elements in the periodic table are termed as groups. According to recommendations of the IUPAC, the groups are numbered from 1 to 18.

Characteristics of Groups

1. Chemical properties of elements depend upon their electronic distribution.
2. The elements in a group possess definite gaps of atomic numbers. These gaps are 8, 8, 18 and 32.
3. Members of a group possess same valence electrons. Alkali metals of groups IA possess one valence electron. The outermost shell of group IIA elements possess two electrons. Thus their valence is two.
4. Valence of an element is given by either (a) number of electrons present in the outermost orbit or (b)

eight minus number of electrons in the outermost orbit.

Characteristics of Periods

1. The valence of an element is either (a) equal to number of electrons in the outermost shell or (b) eight minus number of electrons in the outermost shell.
2. The number of elements in each group depends upon the number of electrons in the corresponding shell.
3. The outermost shell is also called as valence shell.
4. The elements on the left of the period are metals. The elements at the right of period are non-metals.

Periodicity. Repetition of similar properties of elements in a group.

Important terms

Atomic Radius. The distance between the centre of an atom and the outermost electron.

Noble Gases. All the noble gases lie at the end of each period in groups. The electronic configuration of noble gases is $ns^2\ np^6$ in the outermost shell. However, helium is an exception. The electronic configuration of helium is $1s^2$. All the energy levels of noble gases are completely filled. This stable arrangement of electrons cannot be altered easily by addition or subtraction of electrons. Due to stable arrangement of electrons cannot be altered easily by addition or subtraction of electrons. Due to stable electronic configuration these elements show very little chemical affinity.

(i) **Alkali metals.** The group of elements designated as I A in the modern periodic table. e.g., Li, Na, K, Rb and Cs.

(ii) **Alkaline earth metals.** The group of elements designated as II A in the modems periodic table e.g., Be, Mg, Ca, Sr and Ba.

(iii) **Halogens.** The group of elements designated as VII A in the modern periodic table e.g., F, Cl, Br and I. They are non

metals and have seven electrons in the outermost shell.

Transition elements. The elements of groups IB to VIII B and VIII in the long form periodic table. Their properties do not follow the regular progression of the periodic table. Elements of groups IIB i.e., Zn, Cd and Hg and not true transition elements.

Lanthanides. The 14 elements (from atomic number 58 to 71) immediately following lathanum in the modern periodic table. Their properties are quite alike and are placed in one box only.

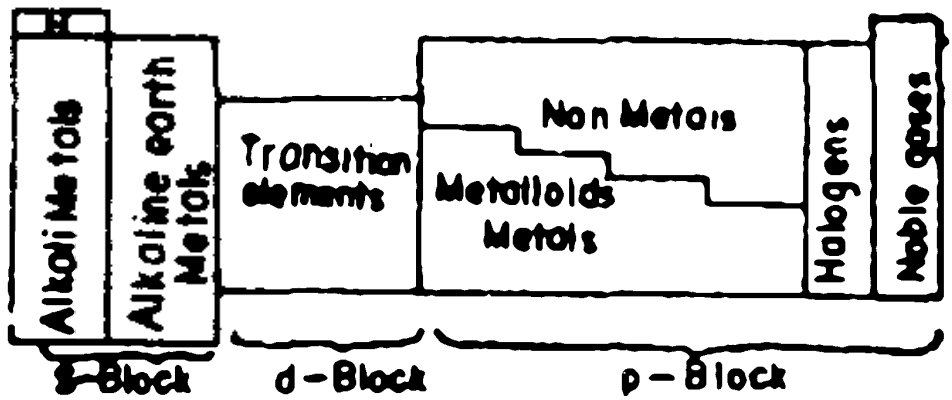


Fig.

Metalloids. The name sometimes given to element that have the intermediate properties between those of metals and non-metals. They form amphotenic oxides.

Actinides. The 14 elements (from atomic number 90 to 103) following actinium in the modern periodic table. Their properties are quite similar and are placed in one box only.

Metals. Elements that tend to form positive ions. They are good conductors of electricity. They form basic oxides.

Non-metals. Elements that tend to form negative ions. They are poor conductors of electricity. They form acidic oxidic.

Advantages of the periodic table

(a) It helps to memorise the characteristics and behaviour of large number of elements in the form of few groups only.
(b) New elements of known properties can be predicted.
(c) With the help of it, the formulae of the compounds and type of bonding can be predicted.

CHEMICAL REACTION

Physical change. Any change that alters the physical properties of a material is known as a physical change. Some physical changes are

1. Making of chisel from steel by a blacksmith.
2. Change of water into steam.
3. Drawing of copper wire from a copper rod.

Chemical Change. The change that converts the chemical properties of a substance is known as a chemical change. Reaction of carbon with oxygen to form carbon dioxide is a chemical change. Burning of magnesium is air to form MgO is a chemical change. This action also known as a chemical reaction.

Chemical Formula. It is the symbolic representation of molecules of a substance. This shows the exact number of atoms of an elements in a substance.

Chemical Equation. A brief representation of number of atoms or molecules taking part in a chemical reaction to form new molecules.

Reactants. Those molecules that take part in a chemical reaction are known as Reactant.

Products. The molecules formed as a result of chemical reaction.

The important reactions are as follows—

(i) **Decomposition reaction.** In this reaction a molecule breaks into elements or molecules.

$2H_2O \xrightarrow{electrolysis} 2H_2 + O_2$

Water → Hydrogen Oxygen

$MgCO3 \xrightarrow{heat} MgO + CO_2$

Magnesium carbonate → Magnesium oxide + Carbon dioxide

(iii) **Displacement reaction:** In this reaction two reactants displace the set of molecules.

$CuSO_4$ + Zn → Cu + $ZnSO_4$

Copper Sulphate + Zinc Copper Zinc Sulphate

Cu + 2 $AgNO_3$ 2Ag + $Cu(NO_3)_2$

Copper + Silver nitrate Silver copper nitrate.

Combination reaction. In this reaction the reactants combine to form new products.

2Mg + O_2 → 2MgO

Magnesium Oxygen Magnesium oxide

CaO + H_2O $Ca(OH)_2$

Calcium oxide water Calcium hydroxide.

(iv) **Isomerization reaction.** Sometimes a compound changes to new compounds under the action of heat etc. i.e. a compound changes from one structural form to another. It is known as isomerization reaction.

NH_4CNO → NH_2CONH_2

Ammonium Cyanate Urea

Synthesis. In this process two elements react to make a compound. Iron reacts with oxygen to form Fe_2O_3.

$2Fe3O_2 \rightarrow Fe_2O_3$

Iron Oxygen Ferric oxide.

Thus synthesis is the process in which two elements react to form a compound. It is a form of combination reaction.

Exothermic reaction and Endothermic reactions. (a) Those reactions in which heat is evolved are known as exothermic reactions. When nitrogen combines with hydrogen to form Ammonia, a lot of heat is produced. So, the formation of ammonia is an exothermic reaction.

$$N_2 + 3H_2 \rightarrow 2\ NH_3 + \text{Heat}$$

(b) Those reactions is which heat is absorbed are known as endothermic reactions. When nitrogen and oxygen are heated to a very high temperature (3000°C), they combine to form nitric oxide.

$$N_2 + O_2 + \text{Heat} \rightarrow 2NO$$

If the energy evolved in the formations of

new bonds is less than the energy required to break the old bonds then the overall reaction will be endothermic.

If the energy evolved in the formation of new bonds is more than the energy consumed in breaking the old bonds, then the overall reaction will be exothermic.

Rate of chemical reaction. The chemical reactions occur at different speeds. Some reactions are very fast and occur instantaneously; some are slow and may take minutes to complete; whereas others are very slow and take place in days, weeks or even months. *The rate of* reaction *of a chemical reaction is defined as the change in the concentration of reactions* (*or products*) *per unit time.* Suppose the concentration of a reactant changes from 0·5 mole per litre to 0·3 mole per litre in 10 seconds, then the rate of this reaction is given by

$$\text{Rate of reaction} = \frac{\text{change in con.}}{\text{time}}$$

$$= \frac{(0.5 - 0.3) \text{ mole per litre}}{10 \text{ seconds}} = \frac{0.2}{10}$$

mole per litre per second = 0·02 mol litre^{-1} second^{-1}

Factors Affecting the Rate of Reaction. The rate of reaction depends mainly on the following factors.

1. Rate of encounter between the molecule of the reactants.
2. Concentration of the reactants.
3. Temperature of the reactants.
4. Presence of catalyst.

Methods of Increasing the Rate of Reaction

1. In the case of solid-liquid or solid-gas system, areas of contact has marked effect on the rate of reaction. If lesser is the size of the solid particle, more will be the area of contact. This will increase the rate of reaction.

2. Higher the concentration of the reactants in solution, more will be the rate of reaction.

3. Lesser the pressure of a gas, faster will be the rate of reaction.

4. Stirring or mixing of the reactants increases the rate of reaction.

Compound	*Formula*
Hydrochloric Acid	HCl
Sulphuric Acid	H_2SO_4
Nitric Acid	HNO_3
Hydrogen Peroxide	H_2O_2
Ammonia	NH_3
Methane	CH_4
Silver Nitrate	$AgNO_3$
Zinc Chloride	$ZnCl_2$
Sodium Hydroxide	$NaOH$
Calcium Carbonate	$CaCO_3$
Magnesium Sulphate	$MgSO_4$
Sodium Chloride	$NaCl$
Zinc Sulphate	$ZnSO_4$

Chemical Reaction. Representation of reactants and products in a symbolic manner is known as a chemical reaction. While writing a chemical reaction. The following points should not be missed.

(i) Reactants are written on the left hand side.

(ii) Products are written on the right hand side.

(iii) Reactants are separated with plus (+) sign on the left hand side. It means react with.

(iv) The reactants and products are separated by → sign. The → points the direction of reaction or the products formed.

(v) Products are also separated by + sign on the right hand side.

Factors affecting the Rate of reaction. The rate of reaction depends on the following five factors.

(a) Effect of temperature. (1) Increase in temperature increases the rate of

reaction. (2) Decrease in temperature decreases the rate of reaction.

(b) Physical nature of reactants. (1) Use of a common solvent for the reactants increases the rate of reaction. (2) On increasing the area of contact between reactants, the rate of reaction increases.

(c) Effect of concentration. Increasing the concentration of reactants increase the rate of a reaction.

(d) Effect of a catalyst. A catalyst increases the rate of reaction.

(e) Chemical nature of reactants. Some substances are more reactive hence the rate of reactions is very fast and some substances are less reactive so chemical reaction is too low, for example the reaction of iron with water.

Irreversible reaction. A reaction which proceed only in one direction is called irreversible reaction. For example, when potassium chlorate ($KClO_3$) is heated in the presence of MnO_2 (magnese dioxide) then

oxygen gas is formed.

$$2\,KClO_3 \xrightarrow{Heat} 2\,KCl + 3O_2\,(g)$$

The reverse is not true i.e, KCl and O_2 gas would not combine to reproduce the reactants $KClO_3$.

Reversible reactions. Sometimes the reaction products can react to reform the original reactants. For example, ammonium chloride decomposes on heating to give ammonia and hydrogen chloride. This indicates that as soon as ammonium chloride decomposes to NH_3 and HCl some of NH_2 and HCl formed may react with each other to reform the original reactant: Ammonium chloride.

$$NH_4Cl(s)\ NH_3\,(g) + HCl\,(g)$$

Reactions in which some of the products formed react to give back the reactants are known as reversible-reaction.

Physical equilibrium Add a small quantity of sugar to a large quantity of water at certain temperature, it soon dissolves. If we continue to add more sugar to this solution

then the speed with which it dissolves decreases and finally sugar starts settling down and further addition only increases the dissolved sugar. This is due to the equilibrium which has been established between the dissolved and the undissolved sugar molecules undissolved sugar(s) dissolved sugar(aq). Since there is only a change in the physical state therefore this is known as physical equilibrium.

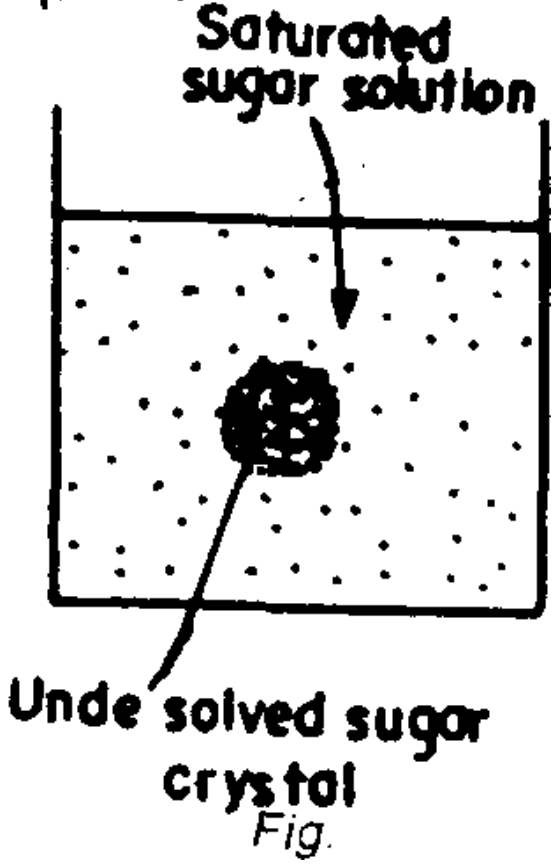


Fig.

Chemical equilibrium. As the time passes in a reversible reaction the rate of forward reaction decreases while that of reverse reaction increases.

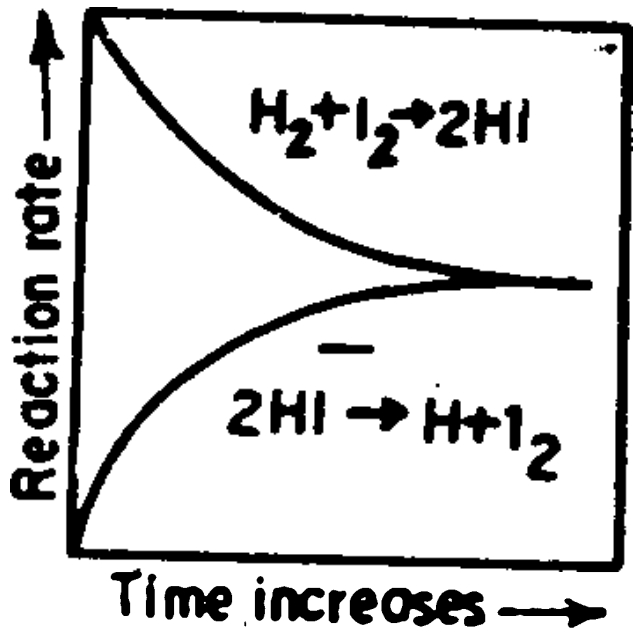


Fig.

At a certain time interval, the two rates become equal and there is no change in concentration of either reactants or products. This is called the (chemical equilibrium). Further at equilibrium state, though the concentrations of reactants and that of products do not change with time but the reaction is

not static. The state is dynamic as conversion of reactants into products and products into reactants continues even after equilibrium is attained. This is called dynamic equilibrium.

Le Chatelier's principle. Due to change in temperature, pressure or concentration. When a reaction is the state of equilibrium is subjected to a stress. The equilibrium shifts in that direction in which the effect of stress can be reduced. i.e

(i) If the temperature is increased, the equilibrium will shift in that direction in which the temperature can be reduced.

(ii) If the pressure is increased, the equilibrium shifts in that direction in which the pressure can be reduced.

(iii) if the concentration is increased, the equilibrium shifts in that direction in which the concentration can be decreased. This is known as Le Chetelier's principle.

Oxidation reaction. A process, in which electron are lost is called oxidation reaction.

$$Na \longrightarrow Na^{+} + e^{-}$$

2,8,1 2,8

Since electrons are lost hence the oxidation is a process in which positive valency is increased.

Reduction Reaction. is a process by which there is a gain of electron e.g., chlorine atom gains one electron to become chlorine ion (Cl^-)

$$Cl + e^{-} \longrightarrow Cl^{-} \text{ (Reduction)}$$

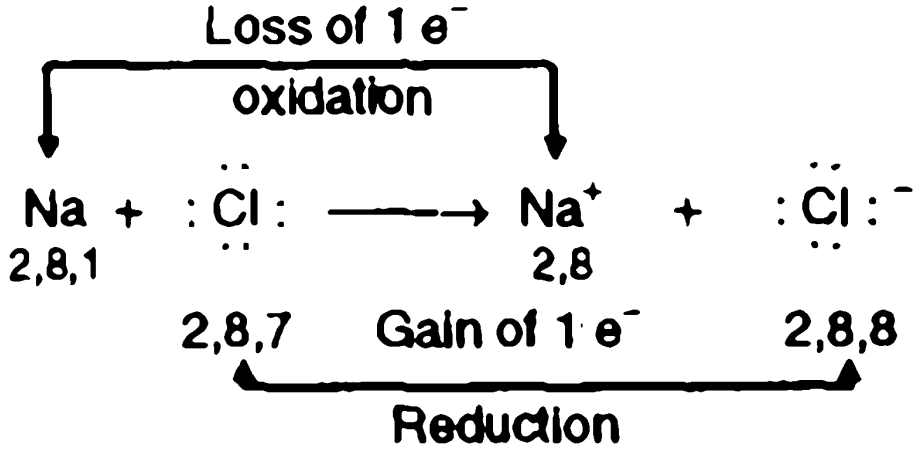
2,8,7 2,8,8

Catalyst. It a substance which increases the rate of reaction but there is no change in the catalyst itself. In the presence of a catalyst, the reactions take place at a faster rate and at lower temperature.

For example, MnO_2 maganese dioxide acts as a catalyst for the decomposition of ($KClO_3$) Potassium chlorate.

Redox reaction. The oxidation and

reduction reactions taking place simultaneously is known as redox reaction.



Here sodium is oxidised and chlorine is reduced.

Electrolytes. A compound which conducts electricity dissolved in water or in molten state is known as an electrolyte. e.*g.* sodium chloride, copper sulphate, caustic soda etc.

Such compounds contain oppositely charged ions which are held together by an electrical attraction. When they are dissolved in water, the electric attraction is broken and ions are set free which act as electricity carriers

$$Na^+ Cl^-(aq) \rightarrow Na^+ + Cl^{-1}$$

Non-electrolytes. A compound which does not conduct electricity when dissolved a water or in molten state is known as non-electrolyte. e.g., cane sugar benzene, etc.

Such compounds contain covalent bonds, they do not ionise when dissolved in water. Therefore they do not conduct electricity.

$CHCl_3(l) \rightarrow$ No ions.

Weak electrolytes	*Strong electrolytes*
Water	Sodium chloride
Ammonia hydroxide	Hydrochloric acid
Calcium hydroxide	Nitric acid
Acetic acid	Sodium hydroxide
Carbonic acid	Copper sulphate
Hydrogen sulphide	Silver nitrates
	Sulphuric acid

Factors which effect Dissociation (or Ionization) of Electrolytes

(1) Nature of electrolyte (2) concentration of the solution (3) Nature of the solvent (4) Temperature (5) Presence of other electrolytes.

Electrolysis. The decomposition of an electrolyte by the action of electric current is known as electrolysis. When sodium chloride is heated, the force of attraction between ions is broken up, the ions become free to move.

The molten sodium chloride contains free sodium ions Na^+, and chloride ions Cl^-

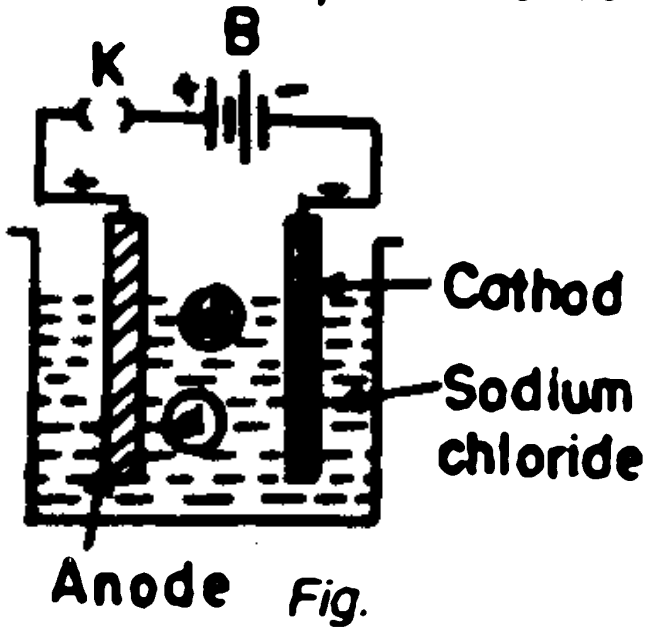


Fig.

and when electric current is passed, the positive sodium ion (Na^+) go to the negative electrode (cathode) where they accept electrons and form sodium atoms.

$$\textit{At cathode}\ Na^+ + e^- \longrightarrow Na$$

As the gain of electrons is called reduction, so the sodium ions are reduced to sodium atoms at the cathode. The negatively charged chloride ions Cl^- go to positive electrode (anode) where they lose electrons and form chlorine atom Cl.

$$\textit{At anode}\ Cl^- - e^- \longrightarrow Cl$$

As the loss of electrons is known as oxidation so the chloride ions lose electrode and get oxidised to chlorine atom. Two chlorine atoms combine to form a chlorine and as a result chlorine gas is formed.

Electrolytic refining. If a thick block of impure copper metal is connected to the +ve terminal of the battery and a sheet of pure copper is connected to the -ve terminal and copper sulphate solution is taken as the electrolyte.

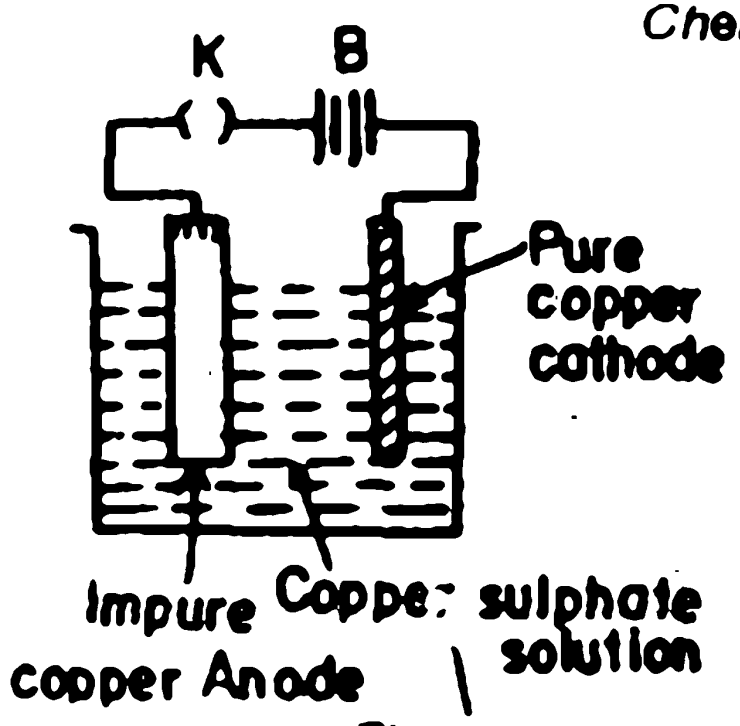


Fig.

$CuSO_4$ solution contains copper ions Cu^{++} and sulphate ions SO_4. On passing the electric current the following reactions take place.

(1) The positive copper ions (Cu^{++}) from the copper sulphate solution go to the negative electrode (cathode) and by taking electrons from the cathode get reduced to copper atoms. These copper atoms get deposited on cathode.

$$Cu^{++} \xrightarrow{+\ 2\ \text{electron}} Cu$$

(2) Copper atoms of the impure anode lose 2 electrons each to the anode and form copper ions Cu^{++}, which go into solution.

$$Cu \xrightarrow{-2 \text{ electron}} Cu^{++}$$

Electroplating. Due to above reaction the process of depositing a superior metal over a baser metal by using electric current is called electroplating. The aim of plating

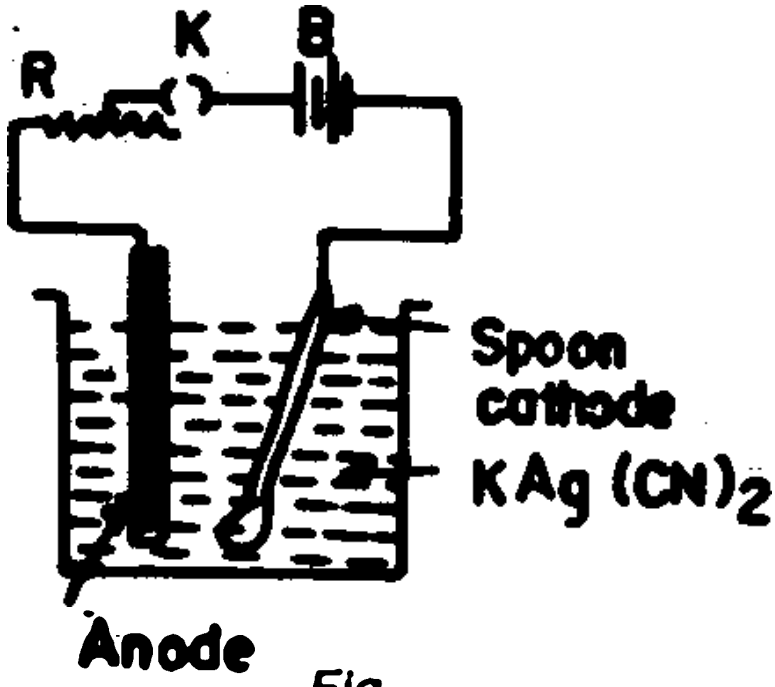


Fig.

may be (1) decoration and (2) preservation. The article to be electroplated is thoroughly

cleaned and made as cathode while the metal to be deposited serves as anode. The electrolyte is a solution of a suitable salt of the metal to be deposited. On passing the current metal ions from the electrolyte get deposited on the cathode and an equivalent amount passes from the anode into the solution. Low temperature, high metal ion concentration and high current density are the conditions for a smooth and bright deposit.

Strong and weak acids. An acid which is completely ionized in water and thus produces a large number of hydrogen ions is called a strong acid. HCl, H_2SO_4 and HNO_3 acids are strong acids because they are fully ionized in aqueous solutions.

$$HCl\ (aq) \rightarrow H^+\ (aq) + Cl^-\ (aq)$$

An acid which is partially ionized in water and thus produces a small number of hydrogen ions are known as weak acid. Acetic acid, carbonic acid etc. are weak acids.

$$CH_3COOH(aq) \qquad H^+(aq) + CH_3COO^-(aq)$$

$$H_2CO_3(aq) \qquad 2H^+(aq) + CO^{2-}(aq)$$

Base. A base (or alkali) which fully dissociated in water and thus produces a large number of hydroxide ions are called a strong base.

Sodium hydroxide, potassium hydroxide are completely ionize in water so they are strong alkalies. Strong alkalies are strong electrolytes.

A base which is only partially ionized in water and thus produces a small number of hydroxide ions is known as a weak base.

Ammonium hydroxide, magnesium hydroxide calcium hydroxide, are weak bases.

Hydronium Ion. The ion formed by the interaction of hydrogen ion of an acid with water molecule is called a hydronium ion. Thus

$$HCl(aq) + H_2O(1) \longrightarrow \underset{\text{Hydronium ion}}{H_2O^{\bullet}(aq)} + Cl^{-}(aq)$$

pH value. Neutural and pure water possess an equal concentration of $H^{\bullet}$ ions and OH^{-} ions and their products is always constant. When an acid is added in water, the

concentration of H^+ ions becomes greater than that of OH^- ions. Similarly when a base is added, the concentration of OH^- ions increases while that of H^+ decreases. Thus an acid solution is one in which the $[H^+]$ is greater than 10^{-7} or a base is one in which the $[H^+]$ is less than 10^{-7}. The acidity or alkalanity of a solution is often expressed by its pH.

The pH value of a solution is defined as the logarithm of the reciprocal of the molar concentration of the hydrogen ion $[H^+]$ in the solution.

$$ph = \log \frac{1}{[H^+]} = -\log [H^+] \text{ or } [H^+] = 10^{-pH}$$

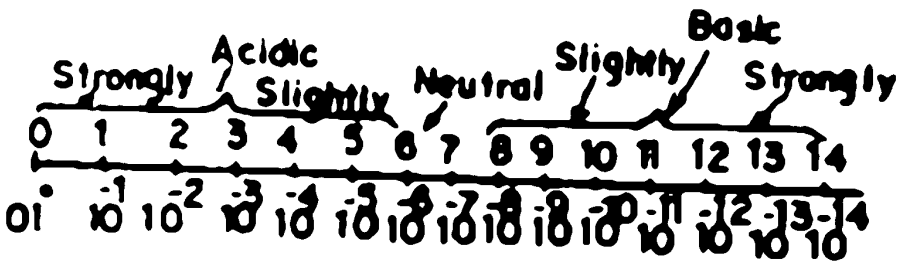


Fig.

A solution becomes more and more acidic if its pH decreases below 7. It becomes more and more basis if its pH increases more than 7.

Importance of pH. (1) By determining the pH of soil it find whether it is acidic or alkaline. This helps in deciding the type of fertilizer. Hence it is very useful for agriculture.

(2) In pure and applied chemistry. This pH values help in determining the conditions of reactions.

(3) A very small variation in pH of blood gives a lot of body ache. So by knowing pH the medium of biological processes like fermentation, enzyme hydrolysis, sterlization etc. can be adjusted. It is very helpful in biological processes.

Chemical Equation. The shorthand method of expressing a chemical reaction with the help of a formula is called a chemical reaction. The substances which combine or react are known as reactants.

The new substances produced as a result of chemical reaction are known as products.

While writing a chemical equation, the reactants are written on the left hand side of an arrow head (——→) and the products on the right hand side of the arrow. Each reactant is separated from another by a (+) sign. Similar is the case with products.

The various abbreviations used in a chemical reaction are (*s*) = Solid, (*l*) = Liquid, (g) = gas, (*aq*) = aqueous solution.

$$3Fe(s) + 2O_2(g) \longrightarrow Fe_3O_4(s) \quad ...(i)$$

$$C_2H_5OH(l) + 3O_2(g) \longrightarrow 2CO_2(g) + 3H_2O(g) \quad ...(ii)$$

A balanced chemical equation has equal number of atoms of different elements in the reactants and the products.

The above chemical equations show that

(1) in equation no (i) three atoms of iron react with two molecules of oxygen to form Fe_3O_4.

(2) in equations no (ii), one molecule of

alcohol burns in 3 molecules of oxygen to form two molecules of carbon dioxide and three molecules of water.

Atomic and Molecular masses. Atomic mass is represented in atomic mass unit (a.m.u.)

Atomic mass of an element is the mass of an atom of the element as compared with carbon taken as 12. Atomic mass of some elements is-

Helium	=	4
Hydrogen	=	1
Oxygen	=	16
Sodium	=	23
Sulphur	=	32

Molecular mass of a substance is defined as the mass of one molecule of a substance as compared with carbon taken as 12.

Molecular masses of some molecules are –

H_2	= 2×1	= 2 a.m.u.
He_2	= 2×4	=8 a.m.u.
O_2	= 2×16	=32 a.m.u.
H_2O	= 2×1 + 16	=18 a.m.u.
Na_2SO_4	= 2×23+32+4×16	= 142 a.m.u.
H_2SO_4	= 2×1+32+4×16	= 98 a.m.u.
HCl	= 1 + 36·5	= 37·5 a.m.u.

Gram Atomic mass. It is the atomic mass of an atom expressed in gramms.

Gram Molecular mass. Is the molecular weight of a molecule of a substance expressed in grams.

Mole. The number of atoms present in gram atomic weight of a substance is called as one mole.

It is a fixed number = $6·02 \times 10^{23}$ atoms.

One mole of H atoms = $6·02 \times 10^{23}$ atoms.

One mole of Na atoms = $6·02 \times 10^{23}$ atoms.

One mole of S atoms = $6·02 \times 10^{23}$ atoms.

Avogadro's number. The number $6·02 \times 10^{23}$ is known as Avogadro's number.

It is equal to one mole of atoms and is written as N.

Number of moles. The number of moles present in a substance can be calculated as under.

Number of moles

$$= \frac{\text{Number of atoms of the element}}{6.02 \times 10^{23}}$$

$$= \frac{\text{Mass of the element in grams}}{\text{Gram atomic mass}}$$

$$= \frac{\text{Number of molecules of the compound}}{6.02 \times 10^{23}}$$

$$= \frac{\text{Mass of compound in grams}}{\text{Gram molecular mass}}$$

Number of moles in 8 gm of oxygen

Solution

No. of moles in 16 gm of oxygen

$$= 6.02 \times 10^{23}$$

No. of moles in 8 gm of oxygen

$$= 3.01 \times 10^{23}$$

Difference between a physical change and chemical change

Chemical change	*Physical Change*
Chemical properties of reactants are changed.	Only physical properties of materials are changed.
New substances are produced.	No new substance is produced.
Energy changes take place.	No energy changes take place.
It cannot be reversed easily.	It can be easily reversed.
Rusting of iron is a chemical change.	Freezing of water, switching on of an electric bulb are physical changes.

Isomers. Compounds having the same molecular formula but different structural formula are known as isomers. (Isomers are very common in organic chemistry).

Balancing of Chemical Equation. Balancing a chemical equation requires the following steps.

(1) Write the correct chemical formula of the reactants towards the left hand side of the arrow.

(2) Write the correct chemical formula of the products towards the right hand side of the arrow.

(3) Write if it is an endothermic or exothermic reaction.

(4) Balance the equation such that number of atoms of elements both the sides are equal.

Some Chemical Reactions- For example here are some chemical reactions.

$CaO + H_2O \longrightarrow Ca(OH)_2 + Heat$

$2Na + H_2O \longrightarrow 2NaOH + H_2$

$CaCO_3 \xrightarrow{Heat} CaO + CO_2$

$2H_2O \xrightarrow[heat]{electricity} 2H_2 + O_2$

$2KClO_3 \xrightarrow{\text{heat}} 2KCl + 3O_2$

$2Mg + O_2 \xrightarrow{\text{light}} 2MgO$

$H_2 + Cl_2 \xrightarrow{\text{pressure}} 2HCl$

$N_2 + 3H_2 \xrightarrow{\text{burning}} 2NH_3$

$2H_2 + O_2 \longrightarrow 2H_2O$

$Mg + CuSO_4 \longrightarrow MgSO_4 + Cu$

$Fe + CuSO_4 \longrightarrow FeSO_4 + Cu$

$Cu + 2AgNO_3 \longrightarrow Cu(NO_3)_2 + 2Ag$

$NaCl + AgNO_3 \longrightarrow AgCl + NaNO_3$

$BaCl_2 + K_2SO_4 \longrightarrow BaSO_4 + 2KCl$

$NH_4CNO \xrightarrow{\text{heat}} NH_2CONH_2$

Ammonium Cyanate → Urea

$2FeSO_4 \xrightarrow{\text{heat}} Fe_2O + SO_2 + SO_2$

$2Al(OH)_3 + 3H_2SO_4 \longrightarrow Al_2(SO_4)_3 + 6H_2O$

$4Li + O_2 \longrightarrow 2Li_2O$

$4Na + O_2 \longrightarrow 2Na_2O$

$2Na + 2H_2O \longrightarrow 2NaOH + H_2 + Heat$

$2K + 2H_2O \longrightarrow 2KOH + H_2$

$2Na + Cl_2 \longrightarrow 2NaCl$

$2K + Br_2 \longrightarrow 2KBr$

$CaCO_3 \xrightarrow[heat]{1070} CaO + CO_2 \uparrow$

$2NaOH + CO_2 \longrightarrow Na_2CO_3 + H_2O$

$NaOH + HCl \longrightarrow NaCl + H_2O$

$Ca + 2H_2O \longrightarrow Ca(OH)_2 + H_2$

$Ca + 2HCl \longrightarrow CaCl_2 + H_2$

$2Ca + O_2 \longrightarrow 2CaO$

$Ca + Cl_2 \longrightarrow CaCl_2$

$Ca + S \longrightarrow CaS$

$4Al + 3O_2 \longrightarrow 2Al_2O_3 + heat$

$2Al + N_2 \longrightarrow 2AN$

$2Al + 6HCl \longrightarrow 2AlCl_3 + 3H_2$

$2Fe(OH)_3 \longrightarrow Fe_2O_3 + 3H_2O(g)$

Iron hydroxide — Iron oxide

$3Fe + 4H_2O \longrightarrow Fe_3O_4 + 4H_2(g)$

$Fe + S \longrightarrow FeS$

$Fe + H_2SO_4 \longrightarrow FeSO_4 + H_2 \uparrow$

$Cu + H_2SO_4 \longrightarrow CuSO_4 + H_2 \uparrow$

$CuCO_3 \xrightarrow{\text{heat}} CuO + CO_2$

$4CuO \xrightarrow{1073\ k} 2Cu_2O + O_2$

$CuO + H_2SO_4 \longrightarrow CuSO_4 + H_2O$

$CuS + H_2SO_4 \longrightarrow CuSO_4 + H_2S \uparrow$

Specific Reaction Rule. Follow the reaction between

$$2NO(g) + O_2(g) \longrightarrow 2NO_2(g)$$

Now the rate of reaction $\propto [No]^2 [O_2]^1$

or rate $= K.[NO]^2 [O_2]$

When concentration of each reactant is unity, then rate constant K = rate of the reaction.

This value of K is known as specific reaction rate.

Molecularity. The number of molecules, atoms on ions that are involved in the rate determining step is known as molecularity. It is always a whole number and never greater than three. In any chemical reaction. The molecularity of four is not desirable, because collision of four particles in a single step is not favourable.

Dalton's Model of an Atom. According to Dalton the following postulates of an atoms is

(1) Matter consists of extremely small particles called atoms.

(2) Atoms of a particular element are all alike but differ from atoms of other elements.

(3) Atoms of a element has a fixed mass.

(4) Atoms of different elements possess different mass and properties.

(5) Atoms are indestructible i.e. they can neither be created nor destroyed.

Modern Atomic Theory. Experiments have proved that

(1) Atom consists of protons, neutrons and electrons.
(2) Atom is no longer an indivisible particle.
(3) Atoms of same element may not be alike. Chlorine has atomic masses of 35 and 37.
(4) Atoms can be changed from one form to another by nuclear fission or fusion.
(5) Atoms of different elements possess same masses. Argon and Calcium have atomic mass of 40 each.

Atomic mass. Mass of an atom of an element as compared to mass of an atom of carbon, taken as 12.

The law of conservation of Mass. States, "matter can neither be created nor destroyed as a result of chemical changes." However, matter can be changed from one form to another. This law is also known as law of Indestructibility of Matter.

Law of Constant Proportions. As described by Proust, "a chemical compound

is always found to be made up of same elements combined together in the same proportion by weight."

The Law of Reciprocal Proportions. It is also known as law Equivalent Proportions. According to this law "weights of two elements A and B, which separately combine with a fixed weight of a third element C, are either the same or simple multiples of the weights of A and B which combine with each other."

Law of Multiple Proportions. As defined by Dalton, "If two elements A and B combine to give two or more compounds, then weights to A which combine with a fixed weight of B, bear a simple ratio to one another."

Gay Lussac's Law of Gases. Defines that, "whenever, gases react, they always react in volumes, which bear a simple ratio (*i*) to one another, (*ii*) to the volumes of the products, if gases are measured in volume under similar conditions to temperature and pressure."

Equation more informative. A chemical equation can be made more informative by using the letters/symbols like(s), (*l*), (*g*) etc. Solid state is indicated by the symbol(*s*) Liquid and gaseous states are indicated by the symbols(*l*) and (*g*) respectively.

Arrows (↑) and (↓) are also used in chemical equations (↑) indicates a gaseous product in the equation. (↓) indicates insoluble product or precipitation in a chemical equation.

An exothermic reaction is indicated by "+Heat" while an endothermic reaction is indicated by "-Heat."

Energy. Capacity to do any work is known as energy. It is measured in Joules(j) or Calorie (1 Calorie = 4.2 Joules).

Bond Energy. is the amount of energy required to break the bond between the atoms at one atmospheric pressure and suitable temperature. The energy of formation of solid sodium chloride is 395.6 K. Joule per mole. 433 KJ heat is required to break/mole of H-H covalent bonds.

Photo Chemical Reactions. The chemical reactions, that produce light, and also the reactions, that proceed by absorption of light energy are known as photo-chemical reactions.

(1) Photosynthesis in plants is carried out in sunlight.

(2) Iodine molecules (I_2) dissociates into Iodine atoms by absorbing visible light.

Uses of Photo-Chemical Reaction

(1) Photographic film contains silver bromide (Ag Br). When light is allowed to fall on this film, then it is chemically affected. On developing, a photographic image is obtained from it.

(2) Evolution of exhaust gases from motors, scooters etc. cause Photo-Chemical pollution.

Electro-Chemistry. is that branch of chemistry which deals with the chemical changes produced by electricity. and

production of electricity by chemical reactions in galvanic cells. Electrical energy is required to form chemical transformation in electolytic cells.

Electrochemical reactions: Reactions involving the flow of current are called electrochemical reactions. The following are different types of electrochemical reactions.

Electrolysis. These reactions require electrical energy from external source to bring about a chemical change.

Electrolysis of Sodium Chloride. When electricity from a battery, is passed through a molten sodium chloride solution, it splits into Na^+ ions and Cl^- ions and sodium deposits on the negatively charged cathode while chlorine is collected at the positively charged anode. This is known as electrolysis. It is used for production of metals is pure form.

Electrolytes. Substances which conduct electricity in the molten state, fused state or aqueous solutions are known as electrolytes.

Conductors. Those substances which allow the passage of current through them are called conductors.

Non-Electrolytes. Substances which do not conduct electricity either in their molten state or through their aqueous solutions.

Weak Electrolytes. Substances which are poor conductors in solution are known as weak electrolytes *e.g.* organic acids, organic bases, water etc. Such substances are poorly ionised in solution.

Strong Electrolytes. Substances which give high conductivities in solutions are called strong electrolytes. Such electrolytes are almost completely ionised in solution *e.g.* mineral acids, salts, alkalies etc.

Electrochemical Cell (Galvanic Cell). These cells are used for production of electricity by chemical reaction Daniel cell is an electro-chemical cell. The working of a Daniel cell is shown below.

Daniel Cell. Consists of a copper vessel and a porous container as shown is Fig. above. The container contains $CuSO_4$ solu-

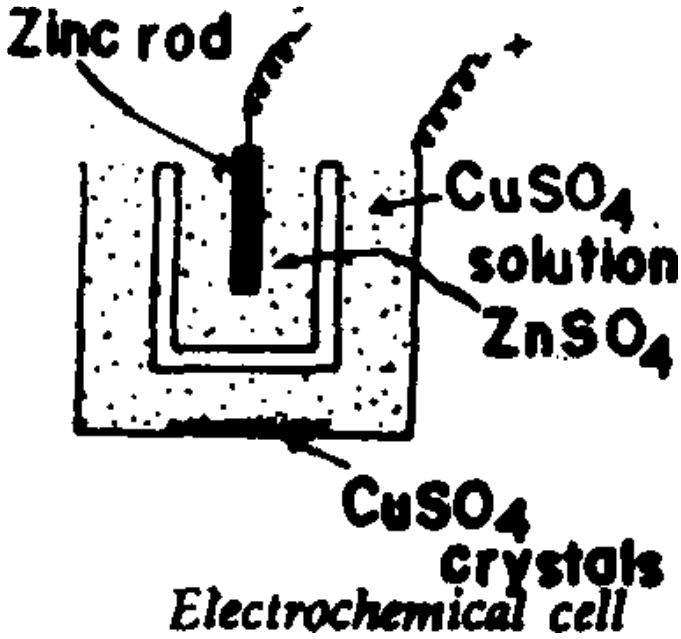


Fig.

tion while the porous pot contains $ZnSO_4$ solution. When copper container and zinc rod are connected through a voltmeter, it shows deflection. It means the current is passing through the wire. Copper container acts as the cathode while zinc rod acts as the anode. Electricity is produced by the following reactions.

$$Zn(s) \longrightarrow Zn^{+2} + 2e^- \text{ (oxidation)}$$

$$Cu^{+2}(aq) + 2e^- \longrightarrow Cu(s) \text{ (reduction)}$$

$$Zn(s) + Cu^{+2}(aq) \longrightarrow Zn^{+2}(aq) + Cu(s)$$

Activity Series of Metals. It is the series in which metals are arranged in the decreasing order of their chemical reactivities. It is known as activity series or electrochemical series of metals. The reactivity series of metals is given below.

K>Na>Ba>Ca>Mg>Al>Zn>Fe>Ni>Sn>Pb>Cu

The more reactive metals easily displace the lesser reactive metal from the salt solution.

Cathode. The electrode connected to the negative terminal of a battery is cathode. It is the electrode where electrons are absorbed.

Anode. The electrode connected to the positive terminal of a battery is known as anode. It is the electrode where electrons are released to generate positive charge.

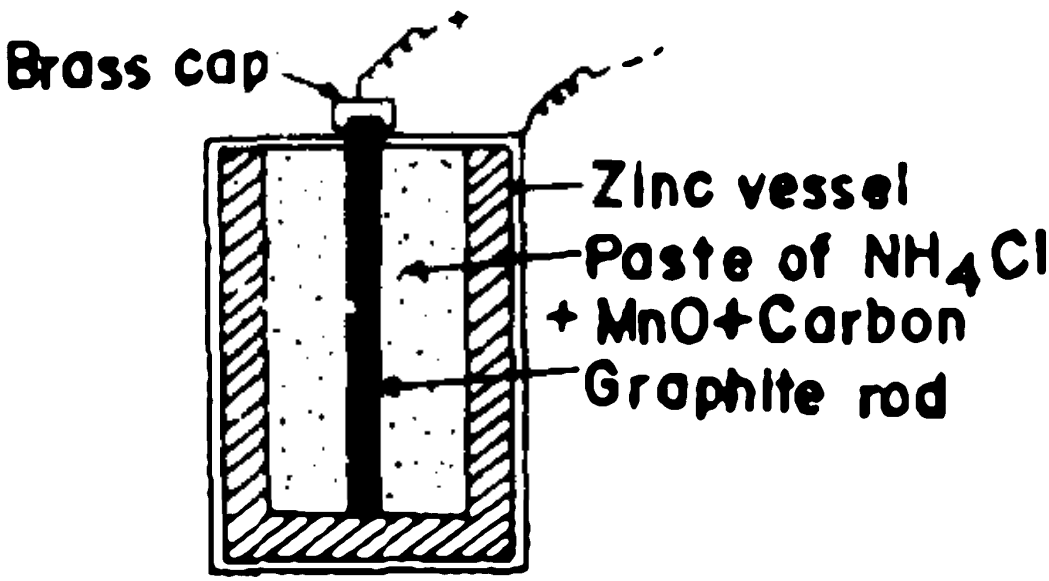
Coulomb. The practical unit of measuring charge is called Coulomb. One Coulomb is the charge flowing through a current of one ampere in one second. One mole electrons

carry a charge of 96500 Coulomb, called Faraday. (Invented by Faraday) Thus

1 Faraday = 96500 Coulomb.

Ampere is a unit of current. If one coulomb of charge flows through an electric circuit in one second, then the current flowing through the circuit is one ampere.

Dry Cell As below shown consists of a zinc container that acts as the anode. At the centre there is a graphite rod that acts as the cathode. The container consists of a paste of ammonium chloride, manganese oxide



Dry Cell Fig.

and carbon. This paste acts as the electrolyte. The zinc coating undergoes chemical reaction and produces zinc ions and electrons.

$$Zn\,(s) \longrightarrow Zn^{+2}\,(aq) + 2e^{-}$$

At cathode

$$2NH_4 + (aq) + 2MnO_2 + 2e \longrightarrow$$

$$Mn_2O_3(s) + 2NH_3(aq) + H_2O(l).$$

The dry cell gives a steady flow of electrons = 1.5 V.

Now a days these cells are used in transistors, toys, cameras, calculators, battery etc. The common ones are silver cells and lithium cells. These cells are used in calculators, watches and cameras.

Storage Cell. Consists of several plates of lead dipped in solution of sulphuric acid. Due to chemical reaction of sulphuric acid on lead, a thin layer of lead sulphate is deposited on lead plates after some time. When current is passed through the circuit, one series of lead plates form lead oxide (PbO_2). The other series act as lead ions.

The cell produces electric current as a result of the following chemical changes.

While charging

$$H_2SO_4 \longrightarrow 2H^+ + SO_4^-$$

$$PbSO_4 + 2H^+ + 2e \longrightarrow Pb + H_2SO_4$$

While discharging

$$PbO_2 + 2H^+ + H_2SO_4 + 2e \longrightarrow PbSO_4 + 2H_2O$$

$$Pb + SO_4 \longrightarrow PbSO_4 + 2e$$

This type of cell can be recharged by passing current. The other varieties of storage cells are (1) nickel-iron and (2) nickel-cadmium cells. These cells are used in the batteries of cars, buses and emergency lights etc.

Rusting. Slow and continuous deterioration of iron due to presence of moisture and oxygen in the atmosphere.

Chemical corrosion. Corrosion due to direct chemical action between the metal and the gases.

Electro-Chemical corrosion. Deterioration of a metal due to flow of electric current in a chemical environment.

Corrosion. Slow and continuous deterioration of metals and alloys by chemical or electrochemical action of environments. e.g. Rusting of iron.

Dry Corrosion. refers to corrosion of metals involving direct chemical action between metals and dry gases.

Wet Corrosion. involves flow of electric current from one point to another through some perceptible distance in the presence of liquid or moisture in air.

Prevention of Corrosion.

(1) By matallic coatings: The surface of metals is coated with zinc, nickel or chromium. It acts as a protective coating on the metal.

(2) Spraying: It is the process of depositing metal or paint over the surface of metal by spray guns.

(3) Paints and vamishes.

(4) Tinning the surfaces.

(5) Plastic coatings.

Galvanising. is the process of deposition of a thin layer of zinc over the surface of iron.

THERMODYNAMICS

Chemical Energetics. It is one of the branches of chemistry which deals with energy changes during various physical processes and chemical reactions.

System. Any specified part of the universe which is under investigation is known as system.

Surroundings. The rest of the universe which is not the part of the system is known as surroundings.

Types of System:

(i) **Open System.** In this system both mass and energy can be exchanged with the surroundings.

(ii) **Closed System.** In this system only energy can be exchanged with the surroundings.

(iii) **Isolated System.** It is the system in which neither mass nor energy can be exchanged with the surroundings.

(iv) **Isothermal System.** This is the system in which the reaction is carried out at constant temperature.

(v) **Adiabatic System.** In this system reaction is carried out at constant enthalpy. In his $\Delta H = 0$, temperature may vary.

(vi) **Isobaric System.** It is the system in which reaction is carried out at constant pressure.

(vii) **Isochoric System.** In this system, reaction is carried out at constant volume.

Intensive properties of a system. Properties of the system which are independent of quantity of matter contained in the system e.g., viscosity, density, refractive index etc.

Extensive properties of a system. Those properties of the system which

depend upon the quantity of matter contained in the system e.g. volume, mass energy etc.

State of a system. It implies the conditions of existence of a particular system when its macroscopic properties have definite values. Any change in macroscopic properties results in a change of state of the system.

State Function. Those thermodynamic parameters which depend only upon the initial and final states of the system and are independent of the path adopted to bring about the change.

Spontaneous Reaction. Reaction which occurs of its own without any outside help is known as spontaneous reaction e.g., formation of white ppt of AgCl when $AgNO_3$ (aq) reacts with NaCl (aq).

$$AgNO_3\,(aq) + NaCl\,(aq) \rightarrow AgCl\downarrow + NaNO_3\,(aq)$$

Internal Energy (E). Internal energy of substance is the total sum of energies stored

in it by virtue of its molecules.

$$E = K.E. + P.E. + E_{trans} + E_{rot} + E_{vib} + ...$$

Internal energy is a state property. The absolute value of internal energy of a system cannot be determined.

Change in internal energy (ΔE)

$$\Delta E = E_2 - E_1$$

E_1 is internal energy in initial state

E_2 is internal energy in final state.

Enthalpy (H). It is defined as "the internal energy plus pressure volume-work."

$$H = E + PV$$

Enthalpy is a state function. The absolute of enthalpy of a system cannot be obtained.

Change in Enthalpy (ΔH) :

$$\Delta H = H_2 - H_1$$

where H_1 is enthaply in initial state and H_2 is enthalpy in final state.

$$\Delta H = \Delta E + P\Delta V$$

Law of Conservation of Energy. This law state "The sum total of the energy of the

universe (system & surroundings) always remains constant. Although one form of energy may be converted into another form." It is also known as First law of thermodynamics.

Mathematically it is expressed as

$$\Delta E = q - W$$

where $q \rightarrow$ is heat energy change

$W \rightarrow$ is work done

$\Delta E \rightarrow$ is change in internal energy.

Hess's Law. According to this law "The enthalpy change in a chemical or physical process is same whether the process is carried out in one step or more steps."

Heat (or Enthalpy) of Formation. It is the amount of heat evolved or absorbed when one mole of a substance is formed from the most stable state of elements.

Heat (Enthalpy) of Sublimation. It is the Enthalpy change that accompanies the conversion of one mole of solid directly into gaseous state at a temperature below its melting point.

Enthalpy of Solution. It is the enthalpy change accompanying the dissolution of one mole of substance in such a large excess of solvent that further addition of solvent does not bring about any enthalpy change.

Bond Energy. It is the average amount of energy required during breaking of one mole of bonds of that type present in a molecule of a gaseous compound. The bond energy of H-H bonds in H_2 molecule is 242.0 KJ/mole.

ΔH = Bond energy of reactants - Bond energy of products.

Calorific Value. It is the energy released in the combustion of one gram of the substance (food or fuel). Its unit is K cal/gm.

$$\Delta H_f = \Sigma H_{(compounds)} = \Sigma H_{(element)}$$

Heat (Enthalpy) of Reaction. It is equal to the amount of heat evolved or absorbed as indicated by a balanced chemical equation.

Heat of Neutralisation. It is the amount of heat released when one gram equivalent of an acid is completely neutralised by a base.

Heat of neutralisation of a strong acid and a strong base is always 13.7 K cal/mole.

Heat of Combustion. It is the amount of heat released by complete combustion of one mole of the substance.

Heat of Fusion. It is the amount of heat required to change 1 mole of substance from solid state to liquid state.

Heat of Vapourisation. It is the amount of heat required to convert 1 mole of a substance from liquid state to gaseous state.

Entropy. Entropy is a measure of degree of disorder of a system. It is denoted by S.

Change in Entropy

$$(\Delta S) = S_{final} - S_{initial}$$

Units of entropy = Jk^{-1} $mole^{-1}$.

Free Energy (G). It refers to the energy available for doing some useful work.

Mathematically, $G = H - TS$

Change in Free Energy (ΔG)

$$\Delta G = H - T\Delta S$$

ΔG is very useful in predicting the spontaneity of a reaction.

For spontaneity ΔG must be negative.

Gib's Humboltz Equation

$$\Delta G = \Delta H - T\Delta S$$

Criterion for spontaneity of a reaction:

From $\Delta G = \Delta H - T\Delta S$, we get the following criterion for spontaneity.

If ΔG is negative or less than zero, the reaction is spontaneous.

If ΔG is equal to zero, the system is in equilibrium.

If ΔG is positive, the process does not occur.

Third Law of Thermodynamics: It states "At absolute zero, the entropy of a perfectly crystalline substance is taken to be zero."

CHEMICAL KINETICS

Chemical Kinetics. is that branch of chemistry which deals with the speed or rate of reaction.

Homogeneous Reactions. When all the reactants of products are in the same physical state, the reaction is said to the homogeneous reaction e.g.,

$NaOH\ (aq) + HCl\ (aq) \rightarrow NaCl\ (aq) + H_2O$

Heterogeneous Reactions. Reactions, where reactants and products are in different physical states, are known as heterogeneous reactions e.g.

$$2HCl\ (aq) + CaCO_3\ (s) \rightarrow CaCl_2\ (aq) + CO_2\ (g) + H_2O$$

Exothermic Reactions. Reactions which are accompanied by evolution

(release) of heat energy are known as exothermic reactions i.e. ΔH is negative or heat of products is less than heat of reactants.

e.g., $O_2(g) + H_2(g) \longrightarrow H_2O(g)$

$\Delta H = -242.7$ KJ/mole

Endothermic Reactions. These are the reactions which are accompanied by absorption of heat energy. i.e. ΔH is positive or heat of products is greater than heat of reactants *e.g.*,

$C(s) + H_2O(g) \rightarrow CO_2(g) + 2H_2O(g)$;

$\Delta H = +131.8$ kJ/mole.

Different Kinds of Chemical Reactions:

(a) Chemical combination

$H_2 + Cl_2 \longrightarrow 2HCl$

(b) Chemical decomposition

$2KClO_3 \longrightarrow 2KCl + 3O_2$

(c) Simple displacement reaction

$Zn + CuSO_4 \longrightarrow ZnSO_4 + Cu$

(d) Double displacement reaction

$AgNO_3 + NaCl \longrightarrow AgCl + NaNO_3$

Rate of Reaction. It is defined as the decrease in concentration of the reactants or increase in the concentration of products per unit time. There occurs an increase in rate of reaction if the concentration of reactants is increased.

For a reaction $A \rightarrow B$,

$$\text{Rate of reaction} = -\frac{\Delta A}{\Delta t} = +\frac{\Delta B}{\Delta t}$$

Reaction rate constant (K) or Specific reaction rate: For a reaction, it is defined as "the rate of reaction when the concentrations of the reactants are unity." The value depends upon (i) order of reaction (ii) temperature.

Average Rate:

$$\text{Average Rate} = \frac{\text{Change in conc.}}{\text{Time involved for change}}$$

$$= \frac{\Delta A}{\Delta t}$$

Instantaneous rate. It is the rate of the reaction determined at a particular moment of time. The average rate approaches the

instantaneous rate as Δt becomes smaller.

Factors which affect the rate of reaction:

(a) Physical state of reactants — rate of reaction increases with increase in surface.

(b) Concentration of reactants-rate of reaction increases with increase in concentration.

(c) Catalyst-it generally increases in presence of catalyst.

(d) Temperature-rate of reaction increases with increase in temperature.

Rate Equation. It is a mathematical expression that shows the relationship between the rate of the reaction and the concentration of reactants.

$$A + B \longrightarrow C + D$$

$$\text{Rate} = -\frac{d(A)}{dt} = -\frac{d(B)}{dt} = +\frac{d(C)}{dt} = +\frac{d(D)}{dt}$$

This equation is called rate equation.

Order of a Reaction. It is equal to the total number of reacting species (ions, atoms or molecules) whose concentration actually changes during the course of a chemical reaction.

For a general reaction

$$A + B + C \longrightarrow \text{Products}$$

If, rate = $K[A]^p.[B]^q.[C]^r$ [rate equation]

where K is rate constant, then order of the reaction = $(p + q + r)$.

Molecularity of Reaction. It is equal to the sum of coefficients of various reactants appearing in a balanced chemical equation.

$$C_{12}H_{22}O_{11} + H_2O \longrightarrow 2C_6H_{12}O_6$$

For the above reaction, molecularity

$$= 1 + 1 = 2.$$

Molecularity is a theoretical concept and its value is always a whole number. If molecularity is one, it is unimolecular. If molecularity is two, it is bimolecular and so on.

First Order Reaction. In case the rate of reaction is found to be directly proportional

to the concentration (first power of concentration) of a single reactant, it is said to be first order reaction. $A \rightarrow$ Products

$$\frac{d(A)}{dt} = \text{rate} = K[A]$$ [rate equation for first order]

Example of First order reaction:

(i) Rate of growth of bacterial culture.

(ii) Rate of growth of population, if there is no change in birth rate and death rate.

(iii) Radioactive disintegration process.

Rate Constant for a First Order Reaction.

$$A \rightarrow B$$

If 'a' is the initial concentration of A and 'x' of it disappears in time 't'. Then concentration of A after time 't' is $(a - x)$, therefore

$$K = \frac{2.303}{t} \log \frac{a}{a - x}$$ Units of $K = \text{sec}^{-1}$.

Second order Reaction. This is a reaction whose rate is directly proportional to the

square of concentration of a single reactant or equal to the concentration of two different reactants.

For such a reaction

$$A + B \longrightarrow \text{Products}$$

$$\text{rate} = K[A][B] \text{ or rate } = K[A]^2$$

$$k = \frac{1}{t(a-b)} \ln \frac{b(a-x)}{a(b-x)}.$$

where a, b are the initial concentration of A and B respectively and $(a - x)$, $(b - x)$ are the concentration of A and B after time 't'. Units of $k = L\ m^{-1}\ sec^{-1}$.

Third order Reaction. This is that reaction whose rate is found to be directly proportional to the cube of the concentration of a single reactant or equal to the square of concentration of one reactant and concentration of another reactant.

$$\text{rate} = K[A]^3; \quad \text{rate} = K[A]^2[B]$$

$$\text{rate} = K[A][B]^2; \quad \text{rate} = K[A][B][C]$$

Units of $K = L^2\ mol^{-2}\ sec^{-1}$.

Zero order Reaction. For such a reaction rate = K [concentration]^0

Units of K = L mol L^{-1} sec^{-1}.

Half-Life of a Reaction. It is the time taken for a reaction to reach the half of its initial concentration. It is denoted by $t_{1/2}$.

For a first order reaction $t_{1/2} = \frac{0.693}{K}$,

where K is the first order reaction constant.

Reaction Mechanism

Collision Theory: Molecules react when they collide in a preferential direction.

Threshold Energy. It is the minimum amount of energy from zero level, the reacting molecules must possess, in order to react. It is denoted by E_T.

Activation Energy. It is defined as, "the extra energy over and above the average potential energy of the reactants which must be supplied to the reactants to enable them to cross over the energy barrier between the reactants and products." It is denoted by E_a.

Activation energy (E_a) = Threshold energy (E_T) – Average energy of reactants (E_R)

i.e. $$E_A = E_T - E_R$$

For fast reactions activation energies are low. For slow reactions activation energies are high.

Theory of Transition State: Chemical reaction occur through an intermediate stage which is known as transition state or activated state.

Particles in collision react only, if, upon impact, they attain the energy of the transition state.

$\Delta H > 0$ endothermic reaction (curve I)

$\Delta H < 0$ exothermic reaction (curve II)

The catalyst reduces the energy of the transition state hence it increases the rate of reaction.

Catalyst's Effect on Equilibrium Constant. A catalyst does not alter the equilibrium constant of a reaction.

Effect of Catalyst on Activation Energy. A catalyst lowers the activation energy.

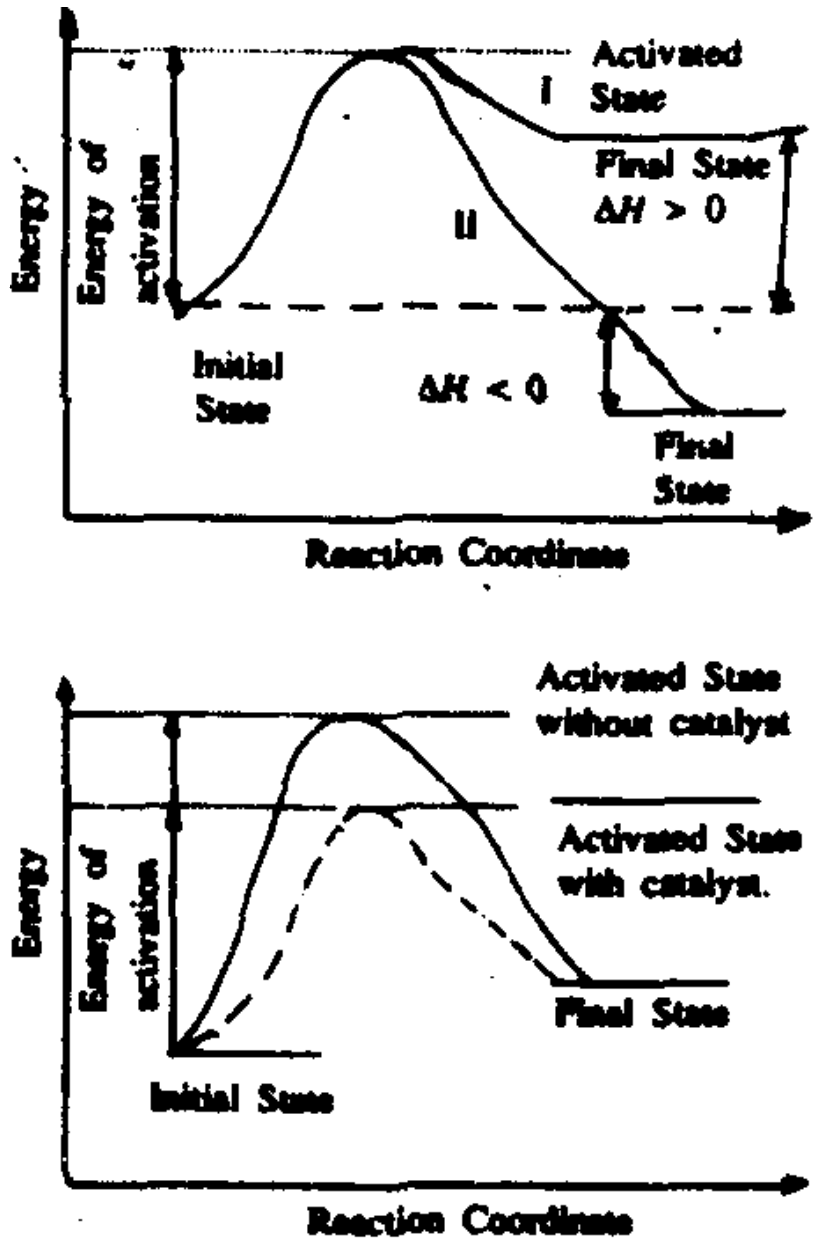


Fig.

Effect of Catalyst on Free Energy Change. A catalyst does not alter the free energy change of the reaction.

Photochemical Reaction. It is the reaction which is brought about by light. The process of photography is based on light, when silver bromide is exposed to light it is decomposed.

$$2AgBr\ (s) \longrightarrow 2Ag\ (s) + Br_2\ (g)$$

Example: (a) Photosynthesis by plants, (b) Bleaching action of sun.

Photosensitisation. Some substances react upon the exposure of light only in presence of a particular substance which is known as photosensitisation. It helps to start the photochemical reaction. Its function is to carry energy e.g. in the photosynthesis of plants, chlorophyll (green pigment in plant leaves) acts as photosensitizer.

CARBON AND ITS COMPOUNDS

Carbon. Of all the elements found in nature carbon forms the largest number of compounds. Carbon compounds are found in many things of our daily life like grain, tea, coffee, sugar etc.

Carbon in the periodic table. The atomic number of carbon is 6. i.e., K(2), L(4) Symbol-C, atomic mass is-12 and symbolic representation is $^{12}_{4}C$. Carbon atom has 4 electrons in the outermost shell (L shell) of its atom. It has been placed in group IV of the periodic table because it has 4 electrons in the outermost shell of its atom.

Organic. The word 'organic' indicates substances derived from plant or animal sources.

Organic compounds. are generally knowing by their non-ionic nature, and their insolubility in polar solvents like water, inflamability, covalent linkage etc.

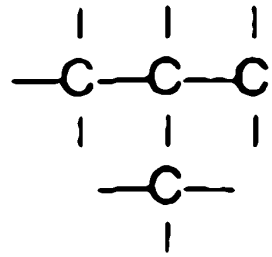
Difference between Organic and Inorganic compounds

Organic Compounds	*Inorganic Compounds*
Organic compounds are usually not solubie in water.	Inorganic compounds are usually soluble in water.
Organic compounds have usually low melting point.	Inorganic compounds have usually high melting point.
Organic reactions are generally slow.	Inorganic reactions are rapid reactions.

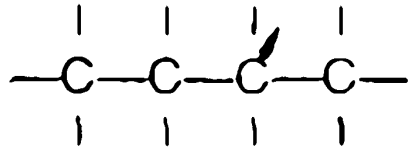
Organic compounds are usually inflamable i.e. catch fire easily.	Inorganic compounds are usually non-inflamable i.e. do not catch fire easily.
Organic compounds are non electrolyte.	Inorganic compounds are good electrolytes.

Reason for the large number of organic compounds. The most important factor for the existence of a large number of organic compounds or carbon compounds is that carbon atom can link with one another by means of covalent bonds to form long chains or rings of carbon atoms.

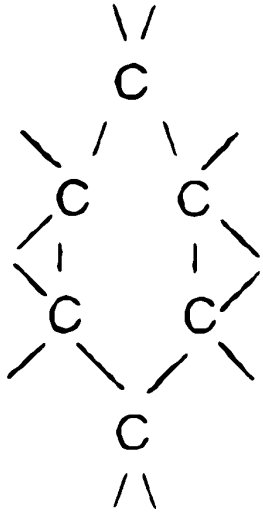
(1) Open chain (branched)



(2) Open chain (Unbranched)



(3) Closed chain (ring)



Sources of organic compounds. The main sources of organic compounds are: sugar, cellulose, starch, dyes and urea in plants and animals.

Toluene, benzene, phenol, naphthalene and anthracene in coal.

Kerosene, petrol, diesel, lubricating oils and vaseline in mineral oils.

Allotropy. When an element possesses two or more different forms in the same state,

they are called allotropes and this condition is known as allotropy.

Allotropy forms of carbon. Carbon occurs in 2 forms in nature. These are in 2 forms i.e.

(A) Crystalline—diamond, graphite.

(B) Amorphous—Charcoal, lamp black.

Diamond. Diamond is crystalline in nature and possesses tetrahedron structure. In diamond structure, each carbon atom is covalently bonded with four carbon atoms at its four corners. Since all the electrons of the carbon atoms in diamond are engaged, leaving no free electrons, thus it is a poor conductor of electricity. The melting point of diamond is 3500°C.

Uses of diamond. Diamond is a hard substance and because of this hardness, therefore it is used for making glass cutters and rock borers for drilling them. It is a non conductor of heat and electricity and it is chemically unreactive. It has high refractive index and is therefore used as a precious

gem for making jewellery etc.

Graphite. Each carbon atom in graphite is covalently bonded to only three neighbouring carbon atoms. Carbon atoms is graphite form layers of hexagonal network separated by comparatively large distances as shown in Fig. Graphite is black in colour, soft, possesses metallic luster and has soapy touch.

Carbon atoms in graphite are weakly bonded to each other by weak wander waals forces. It is a good conductor of electricity and is used as electrodes in electric ore and dry cells.

2.15 Structure of graphite. It consists of easily separable fine sheets. The uniplanar layers consists of six carbon atoms, hexagonally arranged in a benzene ring are held in the crystal by van der waals forces. The hexagon is regular. C-C bond length being 1.92A°. The distance between planes is 3.9 A°.

Each carbon atom in graphite is linked to only three other carbon atoms.

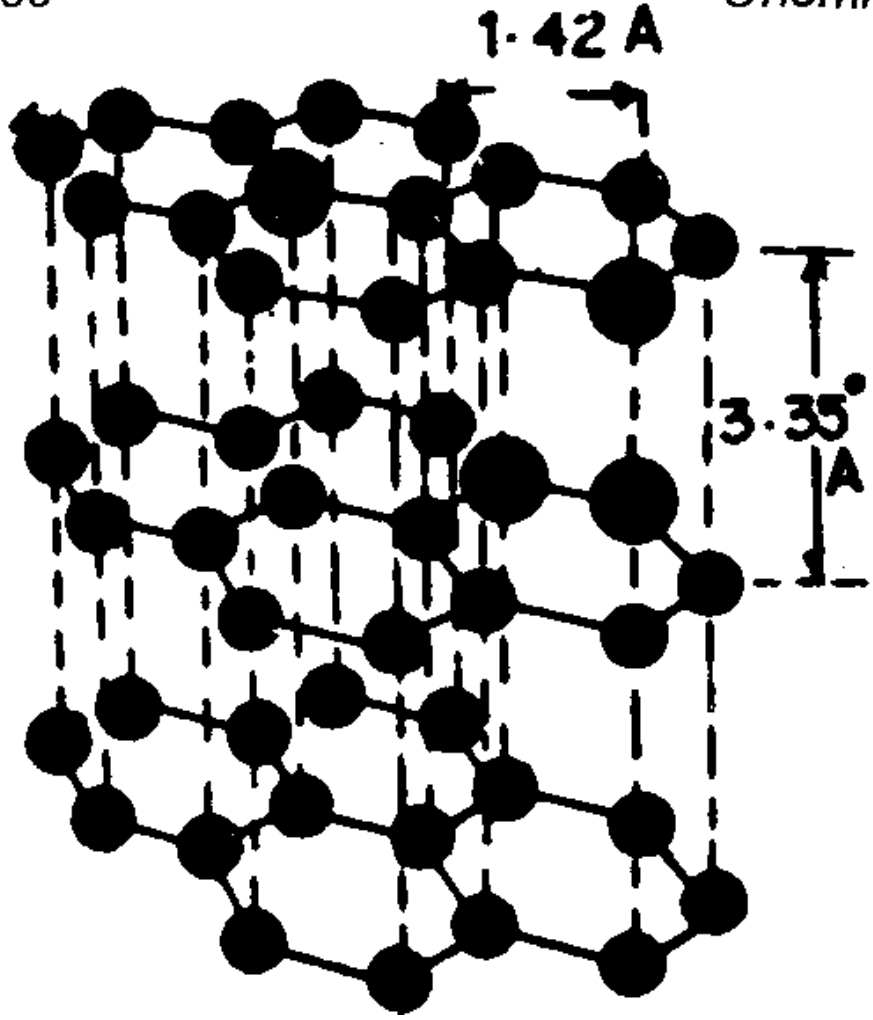


Fig. Arrangement of Carbon atoms in graphite

Chemically graphite is more reactive than diamond. It burns in air at 690°C to carbon dioxide. It is good conductor of electricity. It is used for electrode, lead pencils, for making crucibles for casting of metals. etc.

Diamond	*Graphite*
It is crystalline in nature with all carbon atoms bonded covalently.	It is crystalline with only three carbon atoms forming layers of hexagonal network.
It possesses poor electrical conductivity.	It possess good electrical conductivity.
It is used in jewellery, and for making drilling, boring and grinding tools.	It is used in dry cells as electrodes. It also acts as lubricant.
Its density is 3510 kg/m^3	Its density is 2250 kg/m^3
It is transparent.	It is black and shiny.
It is the hardest substance known.	It is soft.

Nomenclature. The systematic way of naming the organic compounds is known as nomenclature.

IUPAC system. IUPAC the international Union of Pure and Applied Chemistry has devised a method of naming the organic compounds.

These names are known as IUPAC names. For complete understanding of IUPAC names the following points must be remembered.

1. The number of carbon atoms in a hydrocarbon is indicated by using the following stems.

(1) One carbon atom is indicated by 'Meth'
(2) Two carbon atoms are indicated by 'Eth'
(3) Three carbon atoms are indicated by 'Prop'
(4) Four carbon atoms are indicated by 'But' (read as Bute)
(5) Five carbon atoms are indicated by 'Pent'.

2. (1) A saturated hydrocarbon containing single bond is indicated by the word 'ane' i.e. methane, ethane, propane, butane etc.
   (2) An unsaturated hydrocarbon containing double bond is indicated by the word ene i.e. ethene, propene, butene, pentene etc.
   (3) An unsaturated hydrocarbon containing triple bond is indicated by the word Yne' i.e. ethyne, propyne, butyne, pentyne etc.

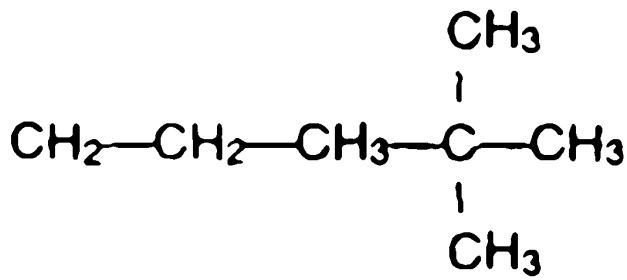
IUPAC nomenclature for branched chain saturated hydrocarbons

(1) First of all find the longest chain of carbon atoms in the structure. The compound is named by the derivative of the hydrocarbon which corresponds to the longest chain.
(2) The alkyl groups present as branches (side chains) are considered as substituents and named separately, like methyl ($-CH_3$) and (ethyl) $-C_2H_3$ groups.

(3) The carbon atoms of the longest carbon chain are numbered in such a way that the substituent (alkyl group) gets the lowest possible number.

(4) The position of the substituent is indicated by writing the number carbon atom to which it is attached.

For example- Name the compound having the formula.

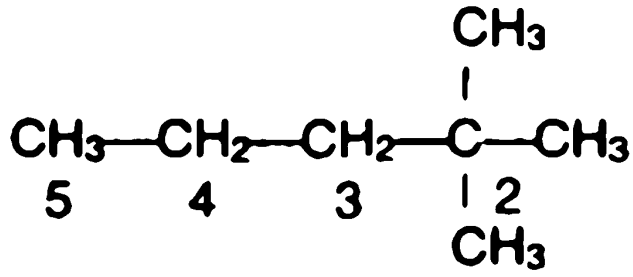


(i) The continuous chain of C atom with maximum number of C atoms is 5, hence it belongs to pentene family.

(ii) The formula contains 2 methyl group hence it is demethyl pentane.

(iii) On numbering the C atoms from left to right the methyl groups come at position 4 which is not acceptable. Hence in this case the numbering should be done from right to left By

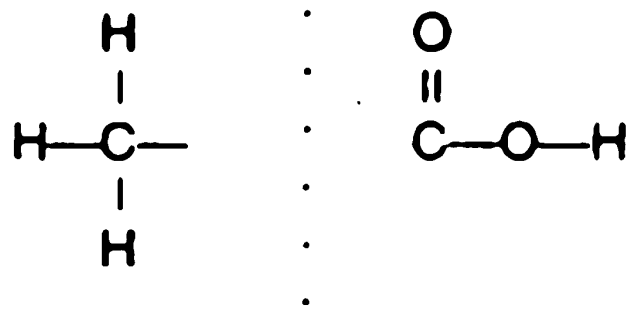
doing so, the two- CH_3 groups are at carbon number 2. i.e.



Group of radical. Chemical compounds (whether organic or inorganic) are usually, made up of two parts each one of which is known as a group or radical.

The properties of chemical compounds are largely due to these groups or radicals.

For example, acetic acid (CH_3COOH) is made up to two groups viz; methyl ($-CH_3$) and carboxylic (-COOH) which mainly govern its properties.



Methyl group Carboxylic group

Hydrocarbons. Compounds made of carbon and hydrogen only are known as contain hydrocarbons. For example, methane (CH_4), ethane (C_2H_6), ethylene (C_2H_4), Acetylene (C_2H_2), are all hydrocarbons.

Simplest hydrocarbons. The simplest hydrocarbon is methane (CH_4).

Position of carbon in methane molecule. In methane the four hydrogen atoms are located at the four corners of a regular tetrahedron, the carbon atom occupying its centre. Thus the angle between any H-C-H is 109° – 28′ as shown in this figure. This is known as space model or tetrahedral structure of carbon atom.

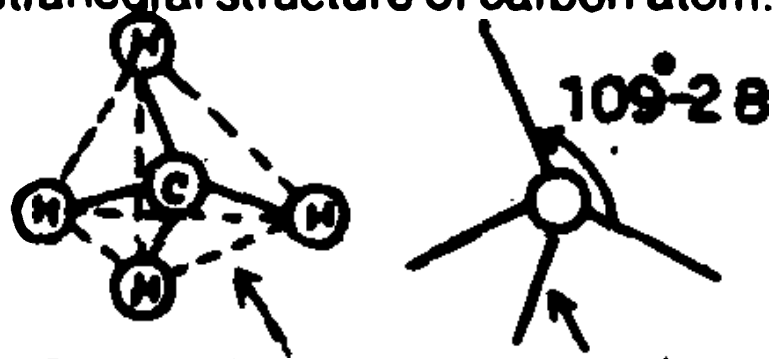


Fig.

This methane gas is prepared by heating sodium acetate with soda lime (sodium hydroxide).

$$CH_3COONa\ (s) + NaOH\ (s) \longrightarrow CH_4\ (g) + Na_2CO_3\ (s)$$

Sodium acetate — sodium hydroxide — methane — sodium carbonate

Methane gas is evolved by downward displacement of water which is collected over water as shown in this figure.

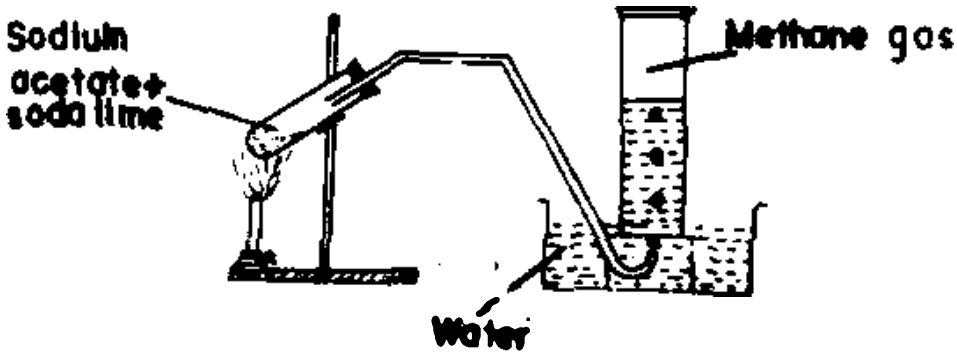
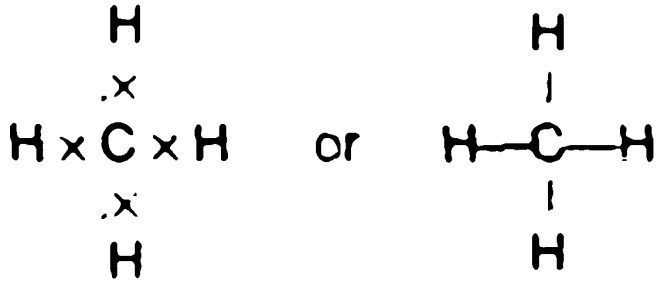


Fig.

Methane is a colourless, odourless and tasteless gas and is insoluble in water. It burns in air with a bluish flame producing carbon dioxide and water with evolution of some heat, i.e.

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O + \text{heat}$$

Hence the Structure formula of methane is–



Marsh gas. Methane is also known as marsh gas because it is formed by the decomposition of plants under stagnant water, in absence of air.

Homologous series. A homologous series is a group or family of compounds which contains the same functional group but have different chain lengths. Thus these have the same chemical properties but different physical properties that vary in a regular manner.

Characteristics of a homologous series are:

(i) It has a general formula in terms of number of carbon atoms.

Homologous Series. A group of organic compounds having similar structures and chemical properties in which the successive compounds differ in molecular formula by CH_2. Homologous series possess the following characteristics.

(1) All members of homologous series can be represented by the same general formula.

(2) Consecutive members differ by CH_2 group.

(3) All compounds of the series show similar chemical properties.

(4) All compounds of the series can be prepared by similar methods.

Homologues of methane. Homologues of methane are ethane, propane, butane and pentane. The molecular formula of Alkanes is C_nH_{2n+2}.

Homologues of Alkynes. C_2H_2, C_3H_4, C_4H_6, C_5H_8 and C_6H_{10}. The molecular formula of alkynes is C_nH_{2n-2}.

Homologues of Alkenes. C_2H_4, C_3H_8, C_4H_8, C_5H_{10} and C_6H_{12}.The molecular formula of alkenes is C_nH_{2n}.

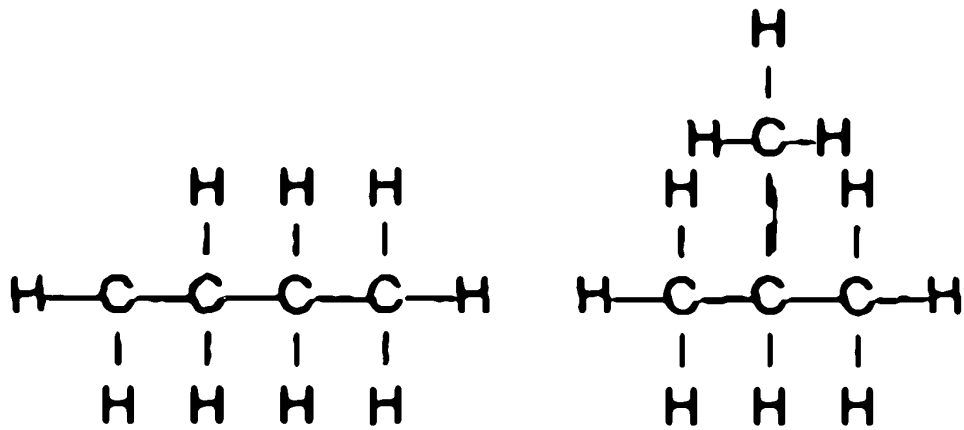
Cracking of alkenes. The process of breaking down of a hydrocarbon of high molecular weight into different hydrocarbons of lower molecular weight is known as cracking

$$\underset{\text{Octane (Higher alkane)}}{C_8H_{18}} \xrightarrow{\text{Cracking}} \underset{\text{Butane (Smaller alkane}}{C_4H_{10}} + \underset{\text{Butane (alkene)}}{C_4H_8}$$

$$\underset{\text{Octane (Higher alkane)}}{C_8H_{18}} \xrightarrow{\text{Cracking}} \underset{\text{Hexane (Smaller alkane)}}{C_6H_{14}} + \underset{\text{Ethane (small alkene)}}{C_2H_6}$$

Isomers. The compounds that contain the same molecular formula but different structures are called isomers. This phenomenon is known as isomerism. ne

isomers of a compound have different physical properties. For example butane with molecular formula C_4H_{10} exists in the following two isomeric forms-



(a) butane (b) Iso-butane

Fig.

Preparation of ethane gas. Ethane gas is prepared by heating a mixture of sodium propionate and soda-lime (sodium-hydroxide). By downward displacement of water ethane gas is collected over water.

$$\underset{\text{Sodium propionate}}{CH_3CH_2COONa\ (s)} + \underset{\text{sodium hydroxide}}{NaOH(s)} \longrightarrow \underset{\text{ethane}}{CH_3CH_3\ (g)} + \underset{\text{sodium carbonate}}{Na_2CO_3\ (s)}$$

Ethane is a colourless and odourless gas which is insoluble in water. Ethane readily dissolves in organic solvents like alcohol, ether. It burns in air with a non-sooty flame to form carbon dioxide and water vapour. A lot of heat is also produced during the burning of ethane.

$$\underset{\text{ethane}}{2\,C_2H_6(g)} + \underset{\substack{\text{oxygen}\\(\text{from air})}}{7O_2\,(g)} \longrightarrow \underset{\text{carbon dioxide}}{4CO_2\,(g)} + \underset{\text{water vapour}}{6H_2O(g)} + \text{Heat}$$

Ethane is quite unreactive because it is a saturated hydrocarbon containing only single covalent bonds.

Substitution. Substitution reactions of ethane with chlorine. Ethane is a saturated hydrocarbon so it reacts with chlorine by substitution.

Ethane used as a gaseous fuel along with methane and other hydrocarbons.

Ethylene. Ethylene is prepared by heating ethyl alcohol with excess of concentrated

sulphuric acid at a temperature of 160°C.

$$\underset{\text{ethyl alcohol}}{CH_3—CH_2OH} \xrightarrow[-H_2O]{\text{conc.}H_2SO_4,\ 160^\circ} \underset{\text{ethylene}}{CH_2 = CH_3}$$

H_2SO_4 acts as a dehydrating agent and removes a water molecules from ethyl alcohol to form ethylene.

This is a colourless gas with a very faint sweet smell and is almost insoluble in water but readily soluble in organic solvent such as ether, alcohol. It burns with a luminous flame giving carbon dioxide and water.

$$C_2H_4 + 3O_2 \longrightarrow CO_2 + 2H_2O + \text{Heat}$$

Oxidation. With cold dilute alkaline permaganate solution ethylene glycol is obtained and the permaganate solution gets decolourised (Baeyer's reagent).

$$CH_2 = CH_2 \xrightarrow[2000\ \text{atm}]{200^\circ\ \text{atm}} CH_3 - CH_2 - CH_2 \longrightarrow$$

$$(CH_2)_n - CH_2 - CH_2 - CH_2 = CH_2$$

Uses. It is used for producing oxy-ethylene flame for welding and cutting metals and is used for manufacturing of plastics. It is also used in the manufacture of ethylene glycol, ethyl alcohol and for the preservation and artificial ripening of green units like orange, bananas and apples.

Polymerisation. Ethylene can be polymerised at about 200°C and under 2000 atm. pressure to the polymer polyethylene)

$$CH_2 = CH_2 \xrightarrow[2000\ atm]{200^\circ C} CH_3 - CH_2 - CH_2 \rightarrow$$

$$(CH_2)_n - CH_2 - CH_2 - CH_2 = CH_2$$

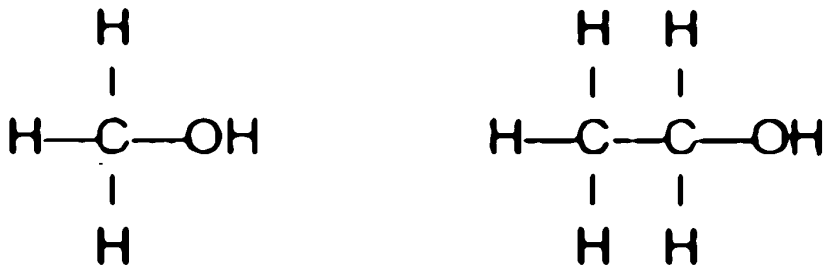
Aliphatic compounds. Open chain compounds are usually known as alipathic compounds.

For example. Propane $- CH_3 - CH_3$,

Acetaldehyde $- CH_3CHO$

Aromatic compounds. The compounds in which at least six carbon atoms are bonded to each other in a ring are called aromatic compounds.

Alcohols. Organic compounds containing —OH as functional group are alcohols or ethanols. Their general formula is $C_nH_{2n+1}OH$. structural formulae of methyl alcohol and ethyl alcohol are given below



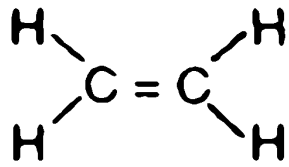
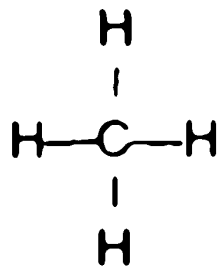
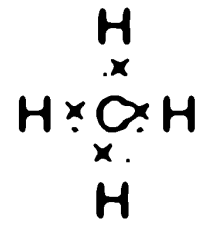
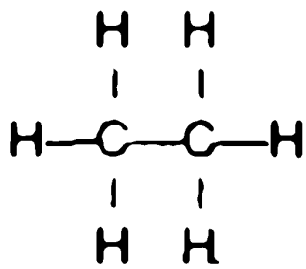
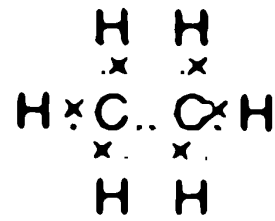
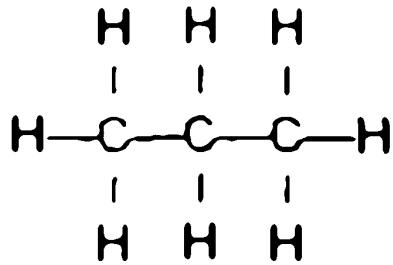
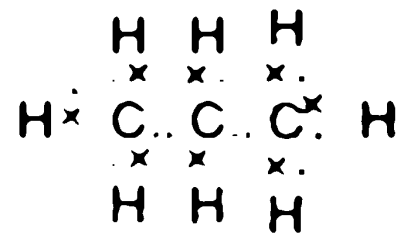
Methyl Alcohol Ethyl Alcohol

Fig.

Alkydes. Organic compounds having —CHO as functional group are known as alkydes.

Carboxyl group. Organic compounds having —COOH as functional group are known as carboxyl or as alkanoic acids.

Structural and electronic formulae of a few organic compounds. The structural and electronic formulae of a few organic compounds are given below.

Com-pound	*Structural formula*	*Electronic formula*
Ethene		
Ethyne	HC ≡ CH	
Methane		
Ethane		
Butane		

Differentiation between alkane and alkene. A jar contains alkane and the other contains alkene. These jars can be differentiated by the following tests.

Reagent	*Alkane*	*Alkene*
Add bromine water	Bromine water retains colour	Bromine water is decolourised
Add reagent $KMnO_4$	Bayer's No action of Bayer's (alkaline reagent	It decolourises alkaline $KMnO_4$ solution.

Manufacture of ethanol. First ethylene is prepared by cracking of petroleum. Ethylene so produced is passed under pressure to conc. sulphuric acid at 75 – 80°C. Ethylene is absorbed in sulphuric acid, and the product is known as ethyl sulphate.

Ethyl sulphate is hydrolysed to get ethyl alcohol.

$$C_2H_4 + H_2SO_4 \longrightarrow C_2H_5HSO_4$$

$$C_2H_4 + C_2H_5HSO_4 \longrightarrow (C_2H_5)_2SO_4$$

$$(C_2H_5)_2.SO_4 + 2H_2O \longrightarrow 2C_2H_5OH + H_2SO_4$$

ethyl alcohol

Ethyl alcohol is also produced by fermentation of molasses (dark coloured liquid left after separation of sugar crystal). The molasses solution is taken in a tank and some yeast is added to it. Then it is allowed to stand for few days at 30°C. Fermentation of sucrose takes place and ethyl alcohol is produced.

METALS AND NON METALS

Metals. Metals are elements (except hydrogen) that form positive ions by losing electrons.

For example. Sodium metal has 1 electron in the outermost orbit of its atom. Which it can lose (donate) to some other atom and form a positively charged sodium ion Na^+

$$Na \xrightarrow{-1\ \text{electron}} Na^+$$

About 80% of the elements known are metals. Metals react with oxygen to form oxides like Na_2O, K_2O, MgO, CaO, Fe_2O_3 and Al_2O_3. Metals are generally solid, (except mercury malleable and ductile. In nature metals are generally found in combined form.

Reactivity of metals largely depends upon the number of electrons present in the valency shell and some metals are more reactive, while the other are less.

Alloys. A systemetic mixture of two or more metals is known as alloy. Steel is an alloy of iron and carbon. The composition of few important alloys is given below.

Alloy	*Elements %*
Steel	Iron and Carbon
Brass	Copper (70%) and zinc (30%)
Cast Iron	Iron and Carbon
Gun metal	Cu (88%), Sn (10%), Zn (2%)
German Silver	Cu (62%), Zn (18%), Ni (20%)
Stainless steel	Iron, nickel and chromium
Muntz metal	Copper (60%), Zinc (40%)
Duralumin	Al and Cu

Ductility. is the property of metals by which metals can be drawn into wires.

Lustre. is the property of a material to reflect light when finely polished. (brightness of surface).

Malleability. is the property of metals by which metals can be hammered/beaten into sheets. The various metals in their decreasing order of malleability are Gold, Silver, Aluminium and Copper.

Mineral. The natural material in the form of which metals are found in nature are known as minerals.

Ores. The minerals from which metals can be extracted profitably are known as ores.

Non-metals. is an elements which form negative ions by losing electrons are known as non-metals. Non-metals contain 4 to 8 electrons in the outermost orbit with the exception of hydrogen and helium.

Difference between metals and non-metals

Metals	*Non-metals*
Metals form positive ions. Good conductors of heat and electricity.	Non-metals form negative ions. Generally poor conductors of heat and electricity. Graphite is an exception which is a good conductor.
Metals are malleable *i.e.* can be beaten into sheets.	Non-metals are generally brittle.
Metals are ductile *i.e* can be drawn into wires.	Non-metals are generally brittle.
Metals are solid at room temp. (except Hg which is a liquid).	Non-metals may be solid, liquid or gases at room temperature.
Metals form basic oxides.	Non-metals form oxides or neutral oxides.

Metals have high melting and boiling points.	Non-metals have comparative poor melting and boiling points.
Metals have high densities (except Na and K).	Non-metals have poor densities.
Metals have good tensile strength.	Non-metals are not strong.
Metals displace hydrogen from dilute acids.	Non-metals do not react with dilute acids.
Metals forms ionic chloride.	Non-metal form covalent chlorides.
Metals form positive ions.	Non-metals form negative ions.
Metals are reducing agents.	Non-metals are oxidising agents.

Reactivity series of metals. The systematic arrangement of metals in a vertical

column in the order of decreasing reactivities is called the reactive series or activity series of metals.

More reactive metals. Those metals which loss electrons easily than hydrogen are said to be more reactive than hydrogen. All the metals which have been placed above hydrogen are more reactive elements.

Less reactive metals. Those metals which loss electrons less readily than hydrogen are said to be less reactive than hydrogen. All the metals placed below hydrogen in the reactivity series are less reactive than hydrogen.

Minerals. The natural materials in which the metals or their compounds are found in earth are called mineral.

Ores. Those minerals from which the metals can be extracted conveniently are called ores. Some common used ores are-

Ore	Metal
Fe_2O_3 (heamatite)	Fe

Fe_3O_4 (magnetite)	Fe
$Al_2O_3.2H_2O$ (bauxite)	Al
$Na_3Al\ F_6$ (cryolite)	Al
$CuFeS_2$ (copper pyrites)	Cu
Cu_2O (cuprite)	Cu
Cu_2S (copper glance)	Cu
$Cu\ (OH)_2CuCO_3$	Cu

Types of ores. The important types of ores which are used for the extraction of metals are, oxide ores; carbonate ores, sulphide ores and halide ores.

Metallurgy. Combination of various processes used for the extraction of metals from their ores are known as metallurgy.

Basic Oxides. These are binary compounds of metal and oxygen. These oxides react with acid to form salt and water.

The various steps involved in the extraction of a metal from its ore are:-

Concentration of the ore. Ores are associated with earthly or rocky materials as impurities. The impurities are called gangue or matrix. The process of removing gangue from the ore is known as concentration of the ore.

Magnetic Separation. Iron and other ores which are affected by magnetic influence can be separated by magnetic separators. The crushed ore is put under the magnetic field on a moving feed belt. The magnetic portion is attracted by magnet. The non-magnetic portion falls from the feed belt unaffected into a separate heap. The magnetic ore like chromite $Fe(CrO_2)_2$ and pyrolisite MnO_2 ore concentrated by this method.

Hydraulic washing. To metallic matter being usually denser than the non-metallic minerals with which it is associated, the heavy substances generally settle down more rapidly when suspended in or agitated with water, and they are less readily carried forward by a running stream of water than

the lighter ores. This causes good separation of non-metallic impurities from the crushed ore. For example ores of tin and lead are heavy, so they are concentrated by this method.

Gangue. The unwanted material or impurities present in the ore is called gangue.

Roasting. The process of strongly heating ores in the presence of air is called roasting. It is mainly carried out to convert sulphide ore into oxide ores.

$$4Fe + 3O_2 \longrightarrow 2Fe_2O_3$$

Calcination. A process of strongly heating an ore at temperature not sufficient to melt in the absence of air is called calcination. Calcination is carried out to convert carbonates into oxides and to remove volatile impurities from ores and also remove water from hydrated ore.

Refining. The process of purification metal is called refining. It is carried out to obtain metals of maximum purity.

Allotropy. The property of metal by vir-

tue of which it shows different physical forms. Phosphorus shows two allotropes. these are (i) White phosphorus and (ii) red phosphorus.

White phosphorus. It is also known as yellow phosphorus. White phosphorus is manufactured by heating a mixture of phosphorite $Ca_3(PO_4)_2$, coke and sand at 1500°C in an electric furnace. The vapours of phosphorus produced are collected under water.

$$2Ca_3(PO_4)_2 + SiO_2 \longrightarrow 6CaSiO_3 + P_4O_{10}$$

$$P_4O_{10} + 10C \longrightarrow P_4 + 10CO$$

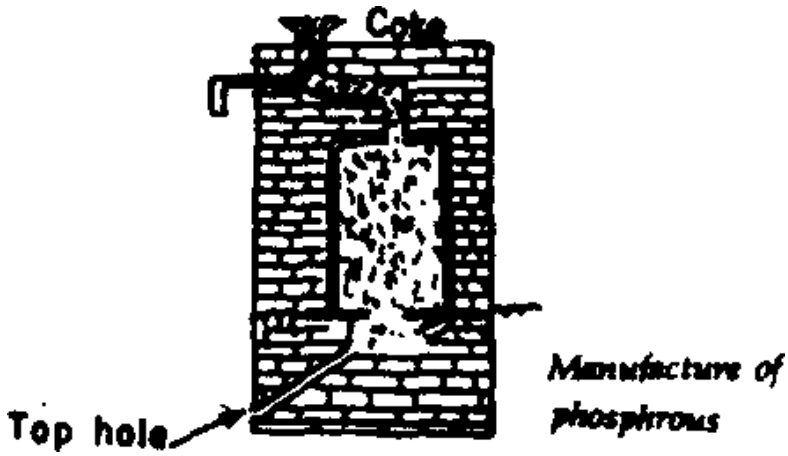


Fig.

White phosphorus possesses the following properties.

Density = 1·8 g/cm^3

Melting point = 44°

Soluble in carbon sulphide

It burns in air and then form phosphorus pentaoxide $P_4 + 5O_2 \longrightarrow 2(P_2O_5)$ Phosphorus pentaoxide

It glows in the dark. This property is known as phosphorescence.

It reacts with chlorine-

$$P_4 + 6Cl_2 \longrightarrow 4PCl_3$$

$$P_4 + 10Cl_2 \longrightarrow 4PCl_5$$

Red Phosphorus. produced by heating yellow variety in an inert atmosphere for several days. It burns in air at 260°C. The density of red phosphorus is 2·3 g/cm^3 and is insoluble in carbon disulphide.

Phosphorescence. White or yellow phosphorus glows when placed in the dark. This property is known as phosphorescence.

Efflorescence. is the process by which a substance gives up water vapours to air.

Fertiliser. Organic or inorganic compounds containing necessary nutrients for making the soil more fertile. It is used for supplying sufficient nutrient to plants for increasing production, known as fertiliser.

Vulcanization. Pure rubber possesses poor strength. When it is heated with sulphur, an appreciable improvement in its properties takes place. This phenomenon is known as vulcanization.

Reaction of metals with oxygen

$4Na + O_2 \longrightarrow 2Na_2O$

$4K + O_2 \longrightarrow 2K_2O$

$2Mg + O_2 \longrightarrow 2MgO$

$2Zn + O_2 \longrightarrow 2ZnO$

$4Fe + 3O_2 \longrightarrow 2Fe_2O_3$

Reaction of metals with dilute acids

$2Na + 2HCl \longrightarrow 2NaCl + H_2$

$Zn + 2HCl \longrightarrow ZnCl_2 + H_2$

$Fe + 2HCl \longrightarrow FeCl_2 + H_2$

Reaction of metals with chlorine

$2Na + Cl_2 \longrightarrow 2NaCl$

$Mg + Cl_2 \longrightarrow MgCl_2$

Reaction of metals with hydrogen

$2Na + H_2 \longrightarrow 2NaH$

$Ca + H_2 \longrightarrow CaH_2$

Production of Iron. Before charging iron ore i.e. haematite (Fe_2O_3) or magnetite (Fe_3O_4) into the blast furnace, (free from impurities) then the ore is concentrated by hydraulic washing and magnetic separation. The concentrated ore is mixed with calculated quantities of coke and limestone and charged in the blast furnace.

Hot air is forced inside the furnace from the bottom. The main reactions taking place inside the blast furnace for making iron can be classified into the following two categories.

(1) Burning of coke to carbon monoxide.

(2) Reduction on haematite to iron.

(1) **Burning of coke:** Coke supplies carbon and heat in the blast furnace. Heat is

needed to melt the oxide ore for its reduction to iron.

Carbon burns to carbon dioxide near the bottom-

$$C + O_2 \longrightarrow 2CO_2 + \Delta$$

As carbon dioxide rises up, it further reacts with carbon to form carbon monoxide-

CO_2	+	C	$\longrightarrow$	2CO
Carbon dioxide		Carbon		Carbon monoxide

(2) **Reduction of iron oxide to iron.** At the upper portion of the surface, haematite ore reacts with carbon monoxide. Haematite is reduced to iron while carbon monoxide is converted to carbon dioxide.

Fe_2O_3	+	3CO	$\longrightarrow$	2Fe	+	$3CO_2$
(Haematite)		Carbon monoxide		Iron metal		Carbon dioxide

Unreacted haematite reacts with carbon to form iron in the lower part of the furnace.

Fe_2O_3	+	3C	$\longrightarrow$	Fe	+	3CO
Iron oxide		Carbon or coke		Iron metal		Carbon monoxide

Iron produced in the blast furnace is in the molten state and taken out from the bottom as shown in Fig.

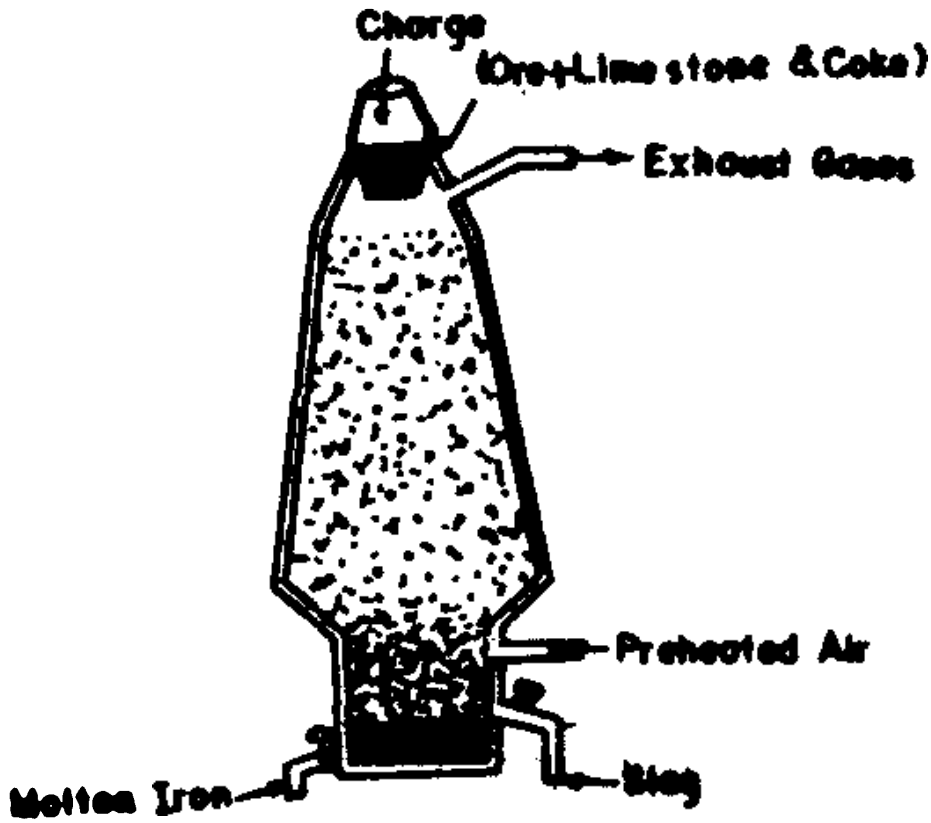


Fig. Blast furnace used for production of pig iron

Symbol = Fe

Atomic mass = 55·85

Atomic number = 26

Position of iron in the periodic table. The electronic configuration of iron is K (2), L (8), M (14), N (2). Though iron has 2 electrons in the outermost shell of its atom, it has not been placed in group II of the periodic table. It is due to the fact that iron is a transition element whose properties are different from the properties of normal elements of group II.

Ores of Iron. The main ores of iron are

(1) Haematite, Fe_2O_3

(2) Magnetite, Fe_3O_4

(3) Limonite $Fe_2O_3.3H_2O$

(4) Siderite $FeCO_3$

(5) Iron pyrites FeS_2.

Properties of Iron

(1) Its melting point is 1539°C.

(2) It is a good conductor of heat and electricity

(3) Pure iron is a grey-white metal.

(4) It appears to be brown due to rusting.

(5) It is one of the few magnetic materials.

Action of oxygen. It does not combine at ordinary temperature, when heated strongly in air or oxygen but it forms a black compound called iron (III) oxide, Fe_3O_4

$$3Fe + 2O_2 \longrightarrow Fe_3O_4$$

Action of damp air. Iron rusts in damp air forming a brown coloured mixture of iron (III) oxide, Fe_2O_3 and iron (III) hydroxide.

$$4Fe + 3O_2 + 3H_2O \longrightarrow Fe_2O_3 + 2Fe(OH)_2$$

Rust

Action with chlorine. Heated iron combines with chlorine forming iron (III) chloride or ferric chloride.

$$2Fe + 3Cl_2 \longrightarrow 2FeCl_3$$

ferric chloride

Reaction with acids. (a) Iron liberates H_2 gas from dil. HCl or H_2SO_4

$$Fe + 2HCl \longrightarrow FeCl_2 + H_2(g)$$

$$Fe + H_2SO_4 \longrightarrow FeSO_4 + H_2(g)$$

with dilute HNO_3 it produces ammonium nitrate and ferrous nitrate

$$4Fe + 10HNO_3 \longrightarrow 4Fe(NO_3)_2 + NH_4NO_3 + 3H_2O$$

with hot conc. H_2SO_4 it produces SO_2, ferrous sulphate and ferric sulphate.

$$Fe + 2H_2SO_4 \longrightarrow FeSO_4 + SO_2 + 2H_2O$$

$$2Fe + SO_4 + 2H_2SO_4 \longrightarrow Fe_2(SO_4)_3 + SO_2 + 2H_2O$$

Conc. HNO_3 makes the iron passive.

Difference between cast iron, wrought iron and steel

Property	*Cast iron or pig iron*	*Wrought iron*	*Steel*
Chemical Composition	Carbon 2.5-4.5%, Iron 96-98%, Impurities P, Si, Mn = 1 5%	Carbon = 1·2-1·25% Iron 98·5-98·8%	Carbon = 5-1·6% Iron 98·5-99.5%.

Welding	can be welded	can be welded easily	can be welded with difficulty.
Magnetisation	Permanently magnetised	same	can be permanently magnetised.
Melting Point	About 1200°C	About 1500°C	1300°C-1400°C
Hardness and malleability	very hard and brittle	Soft and malleabie	Less hard malleabia
Tempering	can be tempered	can not be tempered	can be tempered

Steel is an alloy of iron with usually 0·5 to 1·5 percent of carbon.

Magnese steel contains 7-20% magnese steel. It has high tensile strength and is

most suitable for axles.

Silicon steel contains about 3-4% silicon it is used for transformers.

Tungsten steel contains upto 20% tungsten with small amounts of chromium and vanadium and is used for high speed oils.

Nickel steel containing upto 36% nickel has a negligible co-efficient of expansion and is most useful for clock pendulums etc.

Stainless steel is of many varieties, all contain 11-22% chromium and 1-14% nickel. A thin film of chromium oxide protects the surface from corrosion. These are used for chemical plants and cutlary.

Rusting of Iron is the formation of a red-brown flaky coating of a mixture of iron (III) oxide, Fe_2O_3 and iron (III) hydroxide $Fe(OH)_3$ on the surface of iron metal when it is exposed to humid air or kept in water.

Methods of preventing rusting of Iron.

(1) Rusting of iron can be prevented by coating its surface with metal like tin. aluminium, chromium nickel which

are more resistance to corrosion.

(2) Rusting can be prevented by alloying it with carbon and chromium to get stainless steel.

(3) Rusting of iron can be prevented by galvanization (zinc coating).

(4) Rusting of iron can be prevented by covering its surface with paint, enamels grease, and lacquers.

Alloy is a uniform mixture of one metal with one or more other metals (or Carbon).

Alloys and their uses

Alloy	*Composition of alloy*	*Uses*
Brass	Cu = 60-80%, Zn = 2·0 – 40%	Utensils, condenser sheet
Bronze	Cu = 75-90%, Sn = 10-25%	Utensils, coins and statues

Duriron	Fe = 84.7%, C = 0.8 %, Si =14.5 %	Laboratory plumbing
Gun metal	Cu = 87%, Sn = 10% Zn = 3%	Guns, gears, castings
Coinage alloy	Cu = 75%, Ni = 25%	For making coins
Duralu-min	Al = 95 %, Cu =4%, Mg = 0.5 %, Mn = 0.5%	For making air ships pressure cookers
Type metal	Pb = 82%, Sb = 15%, Sn = 3%	For manufacturing printing types
Solder	Pb = 50%, Sn = 50%	For soldering
Stainless steel	Fe = 73%, C = 1%, Cr = 18%, Ni = 8%	For automobile parts

Invar	Fe = 63%, C = 1%, Ni = 36%	For making meter scale, pendulum rods
Tungs-ten steel	Fe=75-81%, W=14-20%, Cr = 4%, C = 1%	For making high speed cutting tools
Megne-lium	Al=85-99%, Mg=1-15 %	For making balance beams and light instruments.

Annealing. If steel is heated to a temperature well below red hot and is then cooled slowly, the process is called annealing. Annealed steel is soft.

Heat treatment of steel. The steel may be hardened by heating it and then cooling however the properties depend on the way in which it is heated and cooled.

Quenching. If the steel is heated to bright redness and then suddenly cooled by

dipping into water or oil, it becomes most extra-ordinary hard and brittle.

Tempering. The brittless of the quenched steel can be removed without effecting its hardness by quenching Steel is carefully heated to a temperature of 250 – 325°C for a short time and then slowly cooled.

Position of Aluminium in periodic table. The electronic configuration of aluminium is K(2), L(8), M(3). The outermost shell of the atom contains three electrons. This has been placed in group IIIA of the periodic table along with boron, gallium, indium and thallium.

Occurrence. Aluminium does not occur free in nature. The important ores of the metal are: **Oxide**-Corundum (Al_2O_3), diaspore (Al_2O_3 H_2O), bauxite ($Al_3O_32H_2O$) **Fluroide**- Cryloite (Na_3AlF_6) **Silicates**-Felspar ($KAlSi_2O_8$) **Aluminate**-Spinel MgO, Al_2O_3).

Extraction of Aluminium from bauxite ore. Aluminium always occurs in combined state in nature. The two commonly used ores of aluminium are

(1) Bauxite $Al_2O_3\ 3H_2O$

(2) Cryolite Na_3AlF_6

Bauxite is the chief ore of aluminium. Aluminium is extracted from bauxite ore by the following process.

(3) *Purification of bauxite.* Bauxite ore contains sufficient amount of impurities. Powdered bauxite ore is heated with concentrated hot caustic soda solution. Al_2O_3 reacts with NaOH to form sodium meta aluminate and impurities settle down

$$Al_2O_3 + NaOH \longrightarrow 2NaAlO_2 + H_2O$$

(Alumina from Bauxite)	Conc. Sodium hydroxide	Sodium meta aluminate	Water

Sodium meta aluminate is treated with water to form aluminium hydroxide (in the form of precipitates) according to the following reaction.

$$2Al(OH)_3 \xrightarrow{\text{heating}} Al_2O_3 + 3H_2O$$

(Al_2O_3: alumina or aluminium oxide)

Precipitates of aluminium hydroxide are filtered, and heated to get Al_2O_3.

Pure alumina as obtained above is dissolved is cryolite (Na_3AlF_6). The mixture is placed in the electrolytic cell and then electric current in passed through it. The current produces heat and melts the mixture, that acts as electrolyte.

The molten aluminium collects at the bottom and taken out through outlet pipes. The various reactions taking place during the process of electrolysis are given below.

$$Al_2O_3 \longrightarrow 2Al^{+++} + 3O^{-2e}$$

At Cathode $Al^{3+} + 3e \longrightarrow Al$

An anode $O^{-2e} + 2e \longrightarrow O$

$$O + O \text{—} \ddot{A}O_2$$

Extraction of Copper from Pyrites. Copper pyrites ($CuFeS_2$) is the chief ore of

copper.

Copper, symbol Cu, Atomic Number 29, Atomic mass 635.

Concentration by Froth Flotation Process. Sulphide ores are concentrated by froth flotation process. The finely powdered ore is mixed with water and pine oil in a large tank as shown in.

The air is passed through the mixture. The ore particles are preferentially wetted and float on the surface, while impurities settle down. The ore particles are skimmed off from the top.

Roasting. The concentrated ore is roasted in air. It converts copper pyrites to copper sulphide and iron sulphide according to the reaction

$$2CuFeS_2 + O_2 \xrightarrow{\text{Roasting}} Cu_2S + SO_2 + 2FeS.$$

The mixture of copper sulphide and iron sulphide obtained after roasting is mixed with sand and coke and heated in a blast furnace. In this furnace most of the iron sulphide reacts

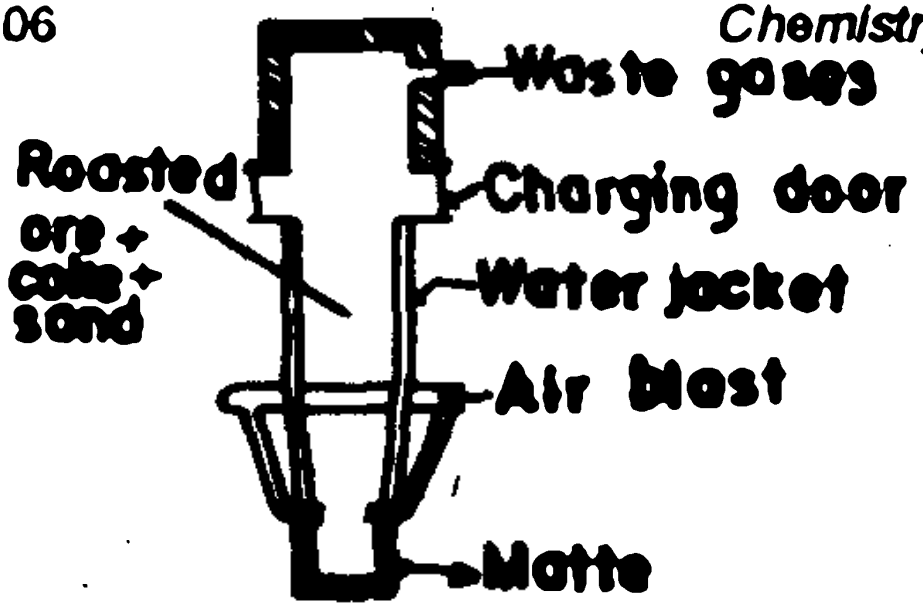


Fig. Blast furnace used in the manufacture of Copper.

with oxygen and is converted into iron oxide.

$$2FeS + 3O_2 \longrightarrow 2FeO + 2SO_2$$

The iron oxide reacts with silica to form iron silicate (slag). It is removed from the top of the molten mixture. The molten mixture of copper sulphide and remaining iron sulphide is known as matte and taken out from the bottom of the blast furnace.

Bessemerisation. The molten mixture of matte is transferred to the Bessemer converter, hot air is blown through it. It converts copper sulphide to copper and the remaining iron sulphide is oxidised to iron oxide.

$$2Cu_2S + 3O_2 \longrightarrow 2Cu_2O + 2SO_2$$

$$2Cu_2O + Cu_2S \longrightarrow 6Cu + SO_2$$

$$2FeS + 3O_2 \longrightarrow 2FeO + 2SO_2$$

Sulphur dioxide escape through the molten matter therefore blisters are formed over the surface of matte. The metal so formed is known as blister copper.

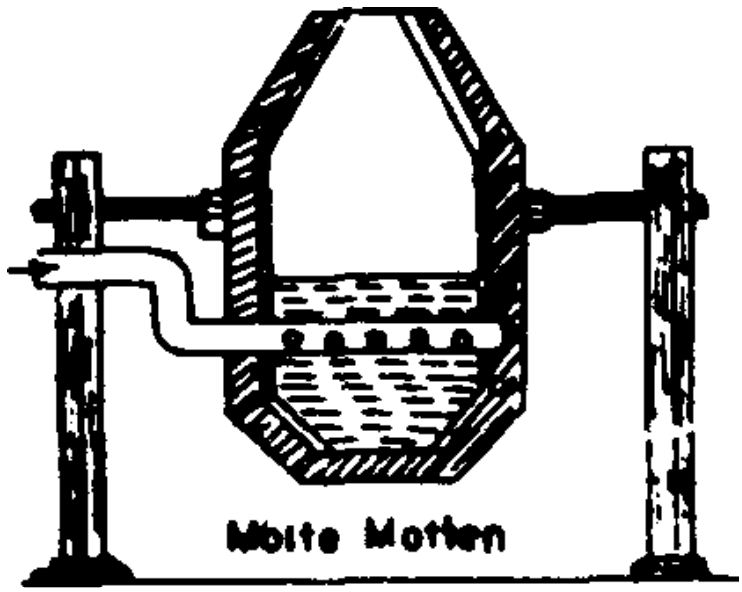


Fig. Bessember converter used for manufacturing copper

Electrolytic refining of copper: Blistered copper obtained from bessemer converter is impure and refined by

electrolysis. A thick plate of impure metal is made the anode while pure metal acts as cathode as shown in Fig. Copper sulphate solution with sulphuric acid acts as electrolyte. By passing electric current, pure metal deposits on the cathode. Copper from anode goes to the solution and is attracted by the cathode according to the following reactions.

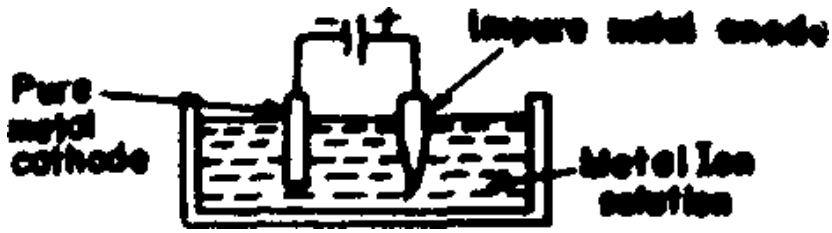


Fig. Electrolytic refining of copper

at cathode

$$\xrightarrow{\text{Reduction}}$$

$$Cu^{+2}(aq) + 2e \longrightarrow Cu \text{ (metal)}$$

$$\xrightarrow{\text{oxidation}}$$

at anode $Cu \longrightarrow Cu^{+2}(aq) + 2e$

Uses of Copper

(I) Electrical wires

(II) Utensiles, boilers and kettles

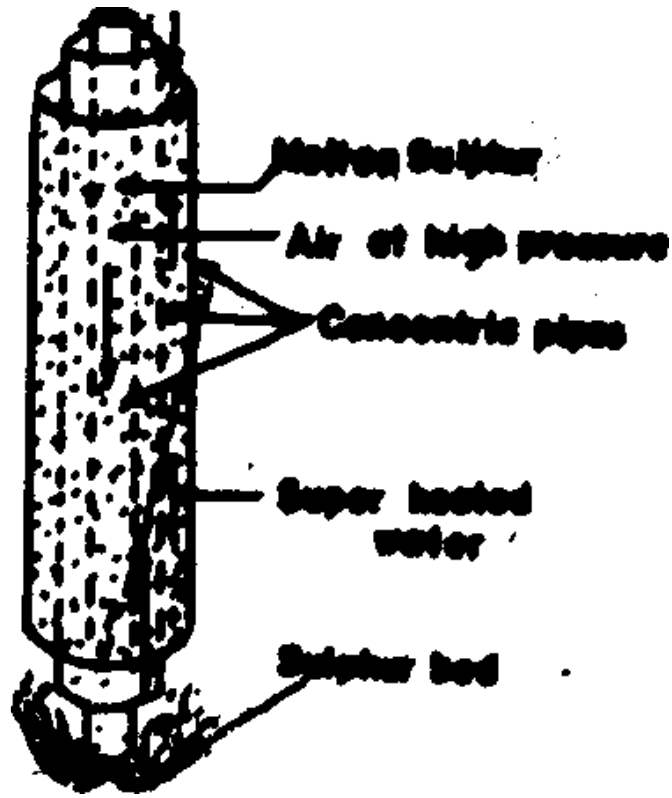


Fig. Frash process used for obtaining sulphur

(iii) Coins and water pipes

(iv) Refrigeration pipes

(v) Alloys like brass, bornze and german silver.

Frash Process of Obtaining Sulphur. The process is used for obtaining sulphur from the interior of the earth. Sulphur has low melting point. The equipment containing three concentric pipes is pushed into the earth as shown in Fig. Through the innermost pipe hot air under pressure is forced. Superheated water (steam) is forced inside the earth through the outermost pipe. The pressure of air and steam forces the molten sulphur out through the middle pipe and then it collects at the top.

Thermit Welding is known as alumino-thermy. This process is based on the principle. "When aluminium powder reacts with iron oxide, a large amount of heat is produced." The mixture of aluminium and iron oxide is known as thermite mixture. When magnesium ribbon is ignited, it produces heat. Due to heat of burning ribbon

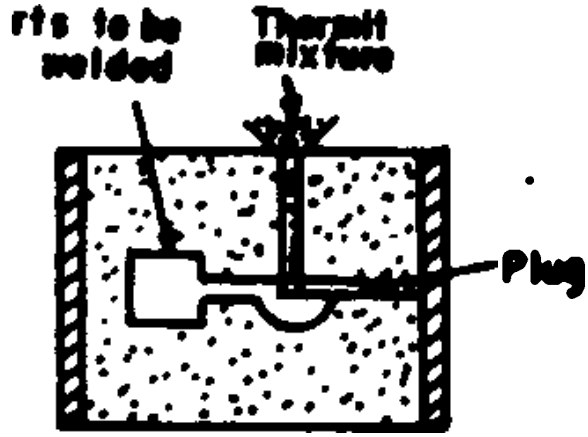


Fig. Thermit welding

aluminium powder reacts with iron oxide to form liquid iron. The liquid iron flows through the runner to the portion to be welded. On solidification it gives a strong weld.

$$2Al + Fe_2O_3 \longrightarrow Al_2O_3 + 2Al + heat$$

SODIUM

Symbol. It's symbol is Na and **Atomic number.** The atomic number is 11 **Atomic mass** is 23

Electronic configuration of sodium The neutral atom of sodium contains 11 electrons. So, the electronic configuration is K(2), L(8), M(1).

Position is periodic table. The sodium

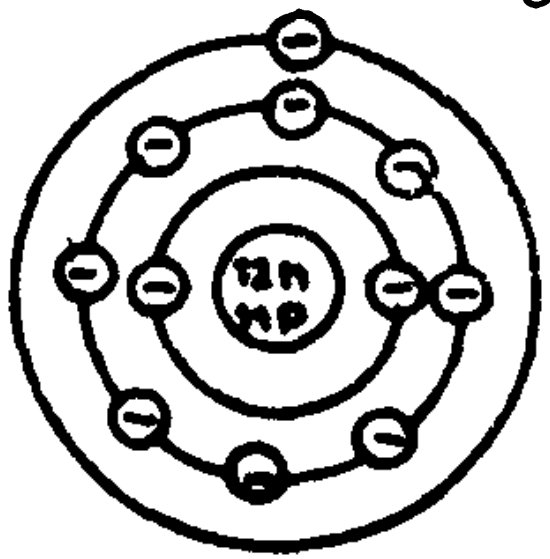


Fig.

has one electron in the outermost shell of its atom, it has been placed in group I of the periodic table alongwith other alkali metals like lithium and potassium.

Occurrence of sodium. Sodium always occurs in the form of its compound (combined state) because it is extremely reactive element.

Natural material	*Chemical Names*	*Formula*
Chile saltpetre	Sodium nitrate	$NaNO_3$
Borax	Sodium Borate	$Na_2B_4O_7 10H_2O$

Rock salt	Sodium chloride	NaCl

Manufacture of Sodium. Sodium metal is prepared on large scale by the electrolytic dissociation of molten sodium chloride. Down's electrolytic cell is used for this purpose, consists of an iron box through the bottom of which rises a circular carbon anode. The anode is surrounded by a ring shaped iron cathode enclosed in a wire gauge shell which also acts as partition and separates the electrolyte. Sodium chloride is mixed with sodium carbonates and melted in the iron tank. On passing electric current. Sodium chloride gets electrolysed producing sodium metal at the cathode and chlorine gas at the anode. Sodium metal collects at the cathode and goes into the reservoir through pipe. Chlorine is taken out through the tube. The following reaction takes place.

$$2NaCl \xrightarrow{\text{Electrolysis}} \underset{\text{Sodium metal}}{2Na} + \underset{\text{Chlorine gas}}{Cl_2}$$

Properties of Sodium. Sodium has low melting and low boiling point and it is a good conductor of heat and electricity. Sodium is very light metal and its density is lower than that of water.

Action of air. Sodium reacts with air to form sodium oxide.

$$4Na + O_2 \longrightarrow 2Na_2O$$

Sodium oxide

Sodium metal is stored under kerosene oil to prevent its reaction with oxygen, moisture and CO_2 of air.

Action with acid. Sodium reacts with HCl to form sodium chloride and H_2.

Action with water. Sodium reacts with cold water to give sodium hydroxide and hydrogen gas.

$$2Na + 2H_2O \longrightarrow 2NaOH + H_2$$

Action with chlorine. When heated, sodium burns in chlorine forming sodium chloride.

$$2Na + Cl_2 \longrightarrow 2NaCl$$

Action with sulphur. Sodium reacts with sulphur to form sodium sulphide.

$$2Na + S \longrightarrow Na_2S$$

Uses. It is used in sodium vapour lamps for street lights.

CALCIUM

Symbol is Ca Atomic number is 20 Atomic mass is 40

Electronic configuration. Calcium atom contains 20 electrons. Therefore the electronic configuration of calcium is K(2), L(8), M(8), N(2).

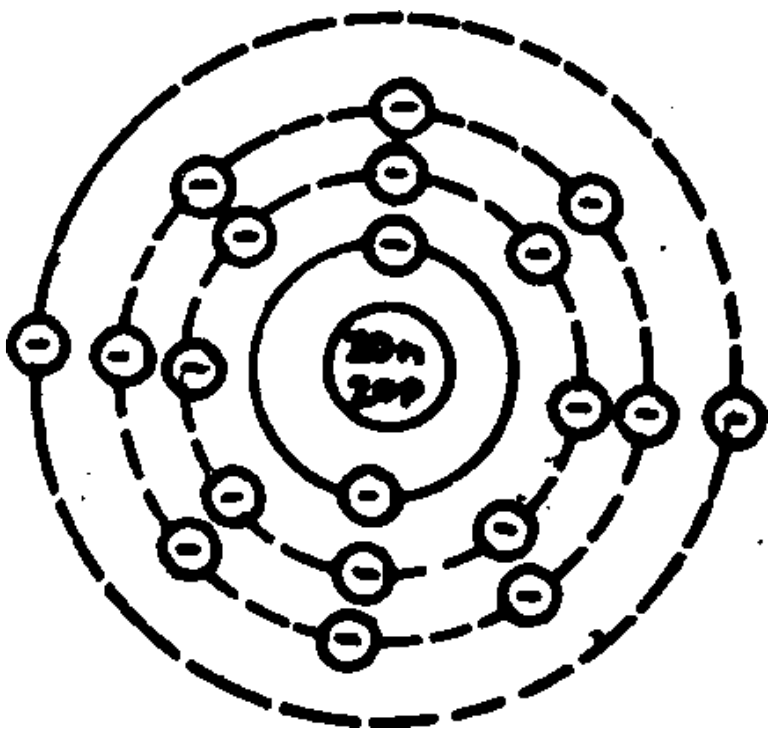


Fig.

Position in the periodic table. Calcium has 2 electrons in the outermost shell of its atom, it has been placed in group II of the periodic table, alongwith other alkaline earth metals like magnesium and beryllium.

Occurrance of calcium. It does not occur as free element in nature. The common naturally occurring materials containing calcium are given below:

Natural material	*Chemical name*	*Formula*
Gypsum	Hydrated calcium sulphate	$CaSO_4.2H_2O$
Fluorspar	Calcium fluoride	CaF_2
Limestone, Chalk, Marble	Calcium carbonate	$CaCO_3$

Preparation of calcium. Calcium metal is prepared on large scale by the electrolysis of molten calcium chloride containing some calcium fluoride to lower the melting point of calcium chloride. Calcium fluoride is added. The molten calcium chloride is electrolysed

by using an iron cathode and a carbon anode. During electrolysis, calcium is produced at the cathode and chlorine is liberated at the anode

$$CaCl_2 \longrightarrow Ca + Cl_2$$

Properties of Calcium. Calcium is a silvery white metal. It has low density. It is melleable, ductile and hard.

Action of air. When exposed to air a white film of calcium oxide is formed. But heated in air or oxygen, it burns with red flame forming calcium oxide.

$$2Ca + O_2 \longrightarrow 2CaO$$

Action of acids. Calcium reacts with dilute. HCi forming calcium chloride and hydrogen gas.

$$Ca + 2HCl \longrightarrow CaCl_2 + H_2$$

Action of water. It reacts with cold water forming calcium hydroxide and hydrogen gas.

$$Ca + 2H_2O \longrightarrow Ca(OH)_2 + H_2$$

If CO_2 gas is bubbled through $Ca(OH)_2$

solution, a white precipitate of calcium carbonate is formed.

$$Ca(OH)_2 + CO_2 \longrightarrow CaCO_3 + H_2O$$

Action with chlorine. On heating calcium burns in chlorine to give calcium chloride.

$$Ca + Cl_2 \longrightarrow CaCl_2$$

Action with hydrogen. When hydrogen gas is passed over heated calcium, then calcium hydride is formed.

$$Ca + H_2 \longrightarrow CaH_2$$

Action with sulphur. On heating calcium reacts with sulphur to form calcium sulphide.

$$Ca + S \longrightarrow CaS$$

Uses of Calcium. Calcium is used as a reducing agent in the extraction of metals like chromium, beryllium, uranium and thorium from the oxides. Calcium is used for removing last traces of air from inert gases. Lead-calcium alloys are very hard and used for making ball bearing in the machines. Slaked lime, $Ca(OH)_2$ is a calcium compound which

is used in white washing and as a disinfectant. Calcium absorbs moisture (water), so it is used as drying agent in the preparation of absolute alcohol.

ZINC

Symbol = Zn

Atomic number = 30

Atomic mass = 65.4

Position of zinc in the periodic table. The electron configuration of zinc is K(2), L(8), M(18), N(2). The outermost shell of the atom contains two electrons. It has been placed in group II of the periodic table.

Occurrence of zinc. Zinc metal is quite reactive, so it does not occur in free state in nature. The main ores of zinc are

(i) Zinc blends, ZnS (ii) Calamine, $ZnCO_3$

Extraction of zinc. Zinc is extracted from its ores mainly by two process:

(i) **Carbon reduction process.** (a) Crushing of the ore to powder form.

Some General Properties of Magnesium and calcium

Element	Atomic	Electronic configuration	Melting point K	Boiling point K	Density
Magnesium (Mg)	12	$[Ne]3S^2$	924	1363	1.74
Calcium (Ca)	20	$[Ar]4S^2$	1123	1765	1.6

In the earth's crust these elements are present in the combined form. The common ores of magnesium are-

Carnalite $KCl.MgCl_2.6H_2O$

Magnesite $MgCO_3$

Dolomite $CaCO_3.MgCO_3$

The common ores of calcium are

Carbonates $CaCO_3$; $CaCO_3.MgCO_3$

Fluorspar CaF_2.

Gypsum $CaSO_4.2H_2O$

Calcium is a strong reducing agent and is used in the extraction of iron. Magnesium

is silvery white in colour. It burns in air to form oxides and nitrides.

$$2Mg + O_2 \longrightarrow 2MgO$$

$$3Mg + N_2 \longrightarrow Mg_3N_2$$

It displaces hydrogen from steam

$$Mg + H_2O \longrightarrow MgO + H_2\uparrow$$

HYDROGEN

Symbol is H, **Molecular** is H_2, **Relative Atomic mass is** 1.008, **Atomic number is** 1

Hydrogen gas consists of diatomic molecules, H_2, having the following structure

H : H or H—H

number

Position in the Periodic table. The atomic number of hydrogen is 1, so its electronic configuration is K (I). It has 1 electron in the outermost shell, so it has been placed in group IA of the periodic table.

Occurrance. Hydrogen does not occur free in nature (except in traces). It occurs in combination with oxygen as water. Hydrogen also occurs in oil and natural gas.

Isotopes of hydrogen. Three isotopes of hydrogen are known as given in table.

Isotope	Nota-tion	*Elec-tron*	*Pro-ton*	*Neu-tron*	*Rela-tive ato-mic mass*
Hydro-gen-1 (protium)	$^{1}_{1}H$	1	1	0	1
Hydro-gen-2 (Deute-rium)	$^{2}_{1}H$	1	1	1	2
Hydro-gen-3 (Tritium)	$^{3}_{1}H$	1	1	2	3

They show different physical properties due to large mass difference. This can be confirmed by comparing the properties of H_2O and D_2O (heavy water).

Heavy water has higher density, freezing point and boiling point than water.

Preparation Hydrogen is prepared in the laboratory by the action of dil H_2SO_4 or HCl on grannulated Zinc. The gas is collected by the downward displacement of water.

$$Zn(s) + H_2SO_4(aq) \longrightarrow ZnSO_4(aq) + H_2(g)$$

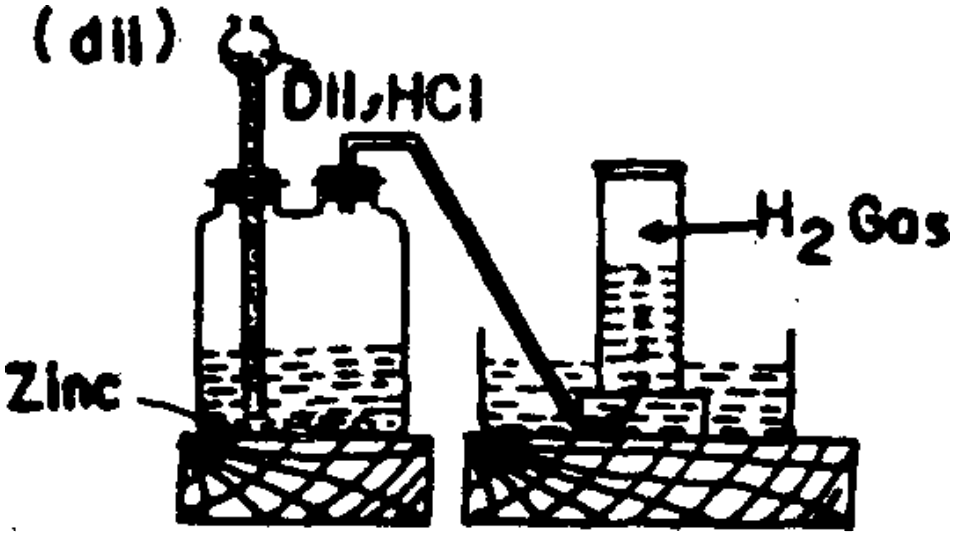


Fig.

To remove any traces of acid the gas is bubbled through KOH solution. Hydrogen can be dried by passing through con-

centrated sulphuric acid or phosphorous pentaoxide. Hydrogen is produced by electrolysis of acidified water.

Properties Hydrogen is a colourless, odourless and tasteless gas which is insoluble in water. Its density is 0.071 g/cm^2. It is lightest known gas. Hydrogen is neither acidic or basic. Hydrogen burns in air (or oxygen) with blue flame (highly inflamable) producing water but it does not support burning.

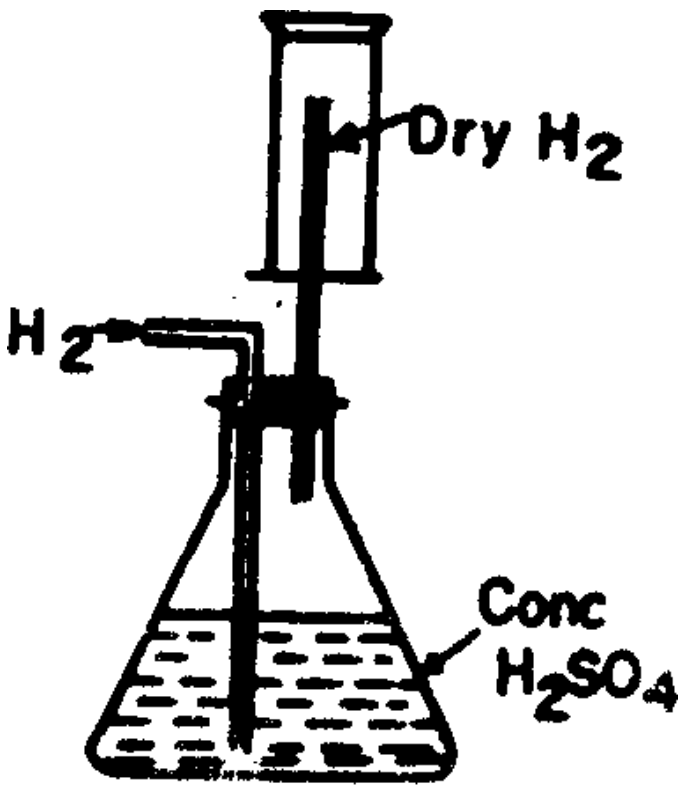


Fig.

$$2H_2(g) + O_2(g) \longrightarrow 2H_2O(l) + \text{heat}$$

Reaction with non-metals. It combines with chlorine in the bright sun light or when its burning flame comes in the contact of chlorine.

$$H_2(g) + Cl_2(g) \longrightarrow 2HCl(g)$$

Hydrogen on passing through boiling sulphur forms Hydrogen sulphide

$$H_2(g) + S \longrightarrow H_2S(g)$$

Reaction with metals. It combines with active metals forming hydrides.

$$2Na(s) + H_2(g) \longrightarrow 2NaH(s)$$

Reaction with compounds. It acts as a reducing agent and reduces metal oxide to their metallic forms

$$CuO(s) + H_2(g) \longrightarrow Cu(s) + H_2O$$

Uses. It is used in the manufacture of petrol.

It is used in manufacture of Ammonia (by Haber's process).

It is used in the manufacture of vanaspati ghee. This process is called hydrogenation or hardening of oils.

The high heat of combustion of H_2 makes it valuable as a fuel.

It is used as a reducing agent in certain metallurgical operations.

Oxy-hydrogen flame which have a temperature (2273K) are used for welding and cutting metals.

OXYGEN

The atomic number of oxygen is 8 and its electronic configuration is $1\,s^2, 2\,s^2, 2\,p^6$. Oxygen is the most abundant element of the earth. It constitute nearly 50% by weight of earth. Oxygen mainly exists in the combined form as silicates, oxides and carbonates of metals.

Water contains nearly 88.8% by weight of oxygen. Air contains nearly 23.2% by weight of oxygen.

Oxygen is prepared by heating potassium chlorate.

$$2KClO_3(s) \xrightarrow{\text{heat}} 2KCl(s) + 3O_2(g)$$

$$2KMnO_4(s) \xrightarrow{\text{heat}} K_2MnO_4(s) + MnO_2(s) + O_2(g)$$

Potassium Permagnate — Potassium magnate — Manganese dioxide

For industrial applications, on a large scale, oxygen is prepared by fractional distillation of liquid air.

Properties. It is a tasteless, odourless and colourless gas. It is slightly soluble in water. It combines readily with metals to form metallic oxides.

$4Na + O_2 \longrightarrow 2Na_2O$

$4K + O_2 \longrightarrow 2K_2O$

$2Ba + O_2 \longrightarrow 2BaO$

$4Na + O_2 \longrightarrow 2Na_2O$

$2Mg + O_2 \longrightarrow 2MgO$

$4Al + 3O_2 \longrightarrow 2Al_2O_3$

$3Fe + 2O_2 \longrightarrow Fe_3O_4$

It also reacts with non-metals

$2H_2 + O_2 \longrightarrow 2H_2O$

$C + O_2 \longrightarrow CO_2$

$S + O_2 \longrightarrow SO_2$

$P_4 + 5O_2 \longrightarrow P_4O_{10}$

Uses. The main uses of oxygen are given below:

Liquid oxygen is used as oxidiser to help in the burning of fuel used in rockets. It is an essential ingredient for breathing. It is used in breathing apparatus for mountaineering.

In steel making processes for lowering the carbon content of steels.

For production of organic compounds.

To form various oxides. Some oxides formed by oxygen are Na_2O, K_2O, CaO, Cr_2O_3, Mn_2O_7, V_2O_5, P_4O_{10}, SO_2, SO_3, CO, CO_2, FeO, ZnO, MnO and MgO.

Air enriched with oxygen is supplied to patients to help them in breathing.

OZONE

In addition to diatomic molecule O_2 oxygen also exists as a triatomic molecule, O_3, known as ozone. O_3 can be said as an allotrope of oxygen. Ozone is produced when ultraviolet radiations or silent electric

discharge is incident on O_2 molecule.

$$3O_2(g) \quad \Leftrightarrow \quad 2O_3(g)$$

A few properties of ozone are as follows-

(A) It is pale blue in colour.

(B) It decomposes readily to give nascent oxygen.

(C) It condenses at 161.2K to a pale blue liquid.

(D) It condenses of 80.6K to a violent black solid.

$$O_3 \longrightarrow O_2 + O$$

The various reactions of ozones are:-

$$H_2S + O_3 \longrightarrow H_2O + O_2 + S$$

$$3SO_2 + O_3 \longrightarrow 3SO_3$$

$$N_2O_4 + O_3 \longrightarrow N_2O_5 + O_2$$

Uses. It is used as a bleaching agent in oils, starch, wax and delicate fabrics.

Ozone exists in the upper atmosphere. Ozone layer absorbs ultraviolet radiations of the sun that are harmful to human beings.

Ozone kills bacteria and is an oxidising agent.

WATER

Water is essential for all forms of life. It is the most abundant compound found in the biosphere. Of the total quantity of water, present in the biosphere, 97.3% is found as saline water in the sea. Only 2.7% water is suitable for drinking.

A molecule of water consists of two hydrogen atoms and one oxygen atom by covalent bond. The structure of molecule of water as it exists in a gaseous state is shown in Fig. The physical properties of water are shown below

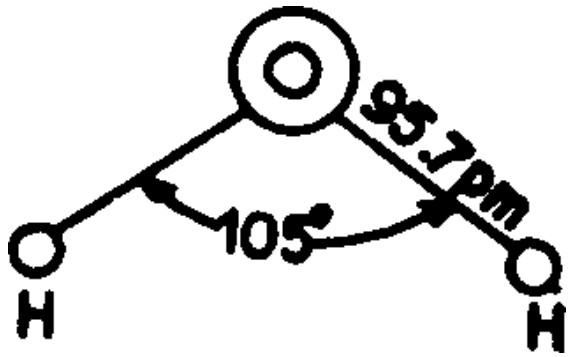


Fig. Molecule of water

Physical properties of water

Property	*Water*
Temperature of maximum density	277.1K
Maximum density	1.000 gm/cm^3
Heat of vaporisation	40.66 kj/mol at 373 K
Molecular weight	18.015
Melting point	273.2 K
Boiling point	373.2 K

HYDROGEN PEROXIDE H_2O_2

In the laboratory hydrogen peroxide is prepared by the action of dilute sulphuric acid on sodium or barium

$$Na_2O_2(s) + H_2SO_4(aq) \longrightarrow Na_2SO_4(s) + H_2O_2(aq)$$

$$BaO_2(s) + H_2SO_4(aq) \longrightarrow BaSO_4(s) + H_2O_2(aq)$$

AMMONIA

Nitrogen is mainly used in industry for preparation of ammonia. It is prepared under high pressure by Haber's process

$$N_2(g) + 3H_2(g) \overset{\text{pressure}}{\Leftrightarrow} 2NH_3(g)$$

ammonia is highly soluble in water and forms ammonium hydroxide.

$$NH_3(aq) + H_2O \Leftrightarrow NH_4OH$$

NITROGEN

The electronic configuration of nitrogen is $1s^2, 2s^2, 2p^3$. It has five electrons in the outermost shell. In the laboratory, it is prepared by treating aqueous solution of sodium nitrite and ammonium chloride.

$$NH_4Cl + NaNO_2 \longrightarrow N_2(g) + 2H_2O + NaCl.$$

It is a tasteless and odourless gas with very low solubility in water. At high temperatures, it combines with metals to form nitrides. $6Li + N_2 \longrightarrow 2Li_3N$

BORON

Boron belongs to group 13 of the periodic table and is the only non-metal of this group.

In the earth crust it mainly occurs as borates and orthoboric acid. The commonly used methods of production of born are. By electrolytic reduction of borates

Reduction of oxides by electropositive metals

$$B_2O_3(s) + 3Mg(s) \longrightarrow 2B(s) + 3MgO(s)$$

By thermal decomposition of boron hydride.

Boron is not a very reactive element. At ordinary temperatures it reacts with strong oxidising agents and nitric acid.

$$2B_2 + 3O_2 \longrightarrow 2B_2O_3$$

$$6B + 6NaOH \longrightarrow 2Na_3BO_3 + 3H_2$$

SILICON

Next of oxygen, it is the second most abundant element of the earth's crust. It is the second member of group 14(IVA) of the periodic table.

The atomic number of silicon is 14. Silicon mainly exists in the combinated state in the form of oxides.

Silicon is prepared in an electric furnace by reduction of silica with coke.

$$SiO_2(s) + C(s) \longrightarrow Si(s) + 2CO(g)$$

(Sand) Coke

Properties. Silicon is very hard and possesses metallic lustre. It combines only at high temperatures with halogens and carbon.

$$Si + 2X_2 \xrightarrow{\text{heat}} SiX_2 \text{ where } (X = Cl, Br, I)$$

$$Si + C \xrightarrow{\text{heat}} SiC.$$

Silicon is a strong deoxidiser and added to steels to remove oxides. Silicon chips are extensively used in electronic components.

NITROGEN

Nitrogen gas is evolved rapidly and is collected over water. Nitrogen gas can also be obtained by heating ammonium nitrite.

Symbol is N; Atomic mass is 14; Molecular formula is N_2; Atomic number is 7; Molecular mass is 28

$$NH_4NO_2 \xrightarrow{\text{heat}} N_2 + 2H_2O$$

Properties of nitrogen

Physical properties of nitrogen is a colourless and odourless gas which is almost insoluble in water. It is lighter than air and also neutral to litmus.

Reaction with metals. Nitrogen combines with some heated metals to form nitrides which are white solids.

$$3Mg + N_2 \longrightarrow Mg_3N_2$$

$$3Ca + N_2 \longrightarrow Ca_3N_2$$

$$2Al + N_2 \longrightarrow 2\,AlN$$

Nitrides decompose on reacting with water producing metal hydroxide and NH_2 gas.

$$Mg_3N_2 + 6H_2O \longrightarrow 3\,Mg(OH)_2 + 2NH_3$$

With Oxygen. Nitrogen combines with oxygen a 3300K to form nitric oxide in very small quantity.

$$N_2 + O_2 \xrightarrow{3300K} 2NO$$

Nitric oxide is thermally unstable and immediately combines with the atmospheric oxygen giving reddish brown fumes of

nitrogen dioxide.

$$2NO + O_2 \longrightarrow 2NO_2$$

With Hydrogen. Nitrogen combines with hydrogen to give ammonia. The reaction takes place at 750 K under high pressure in the presence of finely divided iron catalyst.

Uses of nitrogen

It is used in the manufacture of ammonia, nitric acid and calcium cyanamide.

It can provide inert atmosphere in chemical process.

Can prevent the oxidation of easily oxidizable substances on exposure to air.

It is used for filling electric bulbs.

AMMONIA

Molecular formula - NH_3, Relative molecular mass - 17, **Electron dot structure**

Occurrance of Ammonia. Very small quantity of ammonia is found in air. Decaying of organic matter. *e.g.*, horns and hoofs of dead animals and dead plants produce ammonia gas. It occurs in nature as ammonium chloride, ammonium sulphate.

Preparation of Ammonia. Ammonia is prepared in the laboratory by heating a mixture of ammonium chloride and slaked lime,

$$Ca(OH)_2 - 2NH_4Cl(s) + Ca(OH)_2(s) \longrightarrow CaCl_2(s) + 2H_2O(l) + 2NH_2(g)$$

Finely ground mixture of ammonium chloride (1 part) and slaked lime (2 parts) is placed in a round bottom flask.

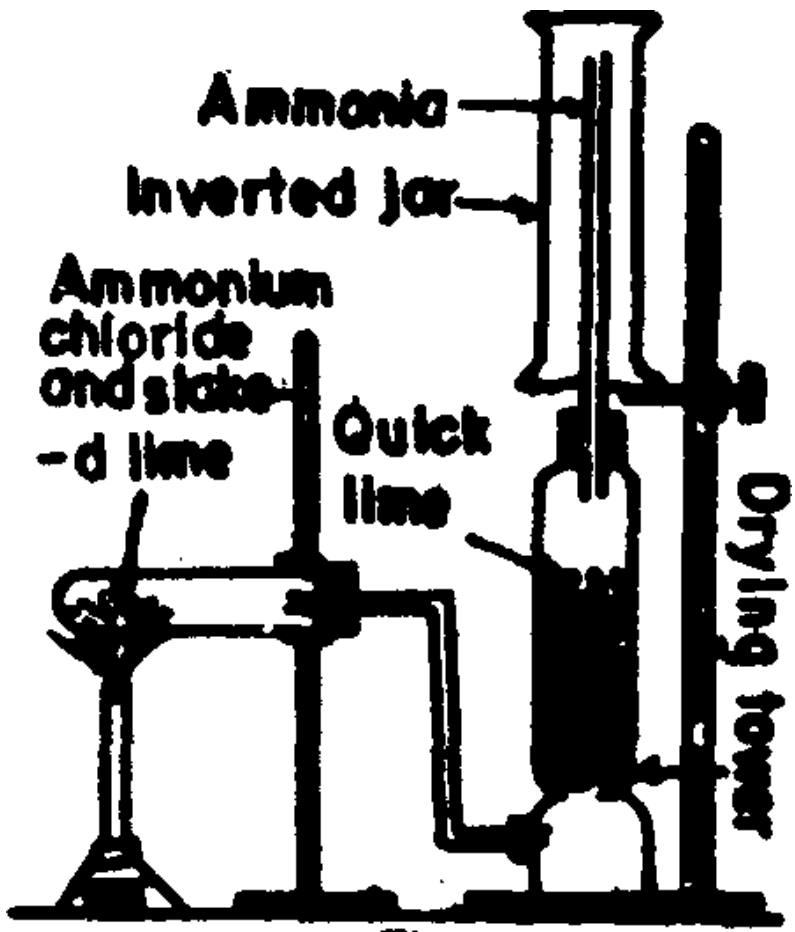


Fig.

On heating NH_3 gas is evolved. The gas is passed through quick lime and collected by the downward displacement of air it is lighter than air.

Water is formed during the course of reaction. It may trickle back on the hot glass and crack it. Therefore flask is always positioned in a titled fashion to avoid the condensed drops.

Manufacture of Ammonia. Ammonia gas is manufactured by Haber's Process.

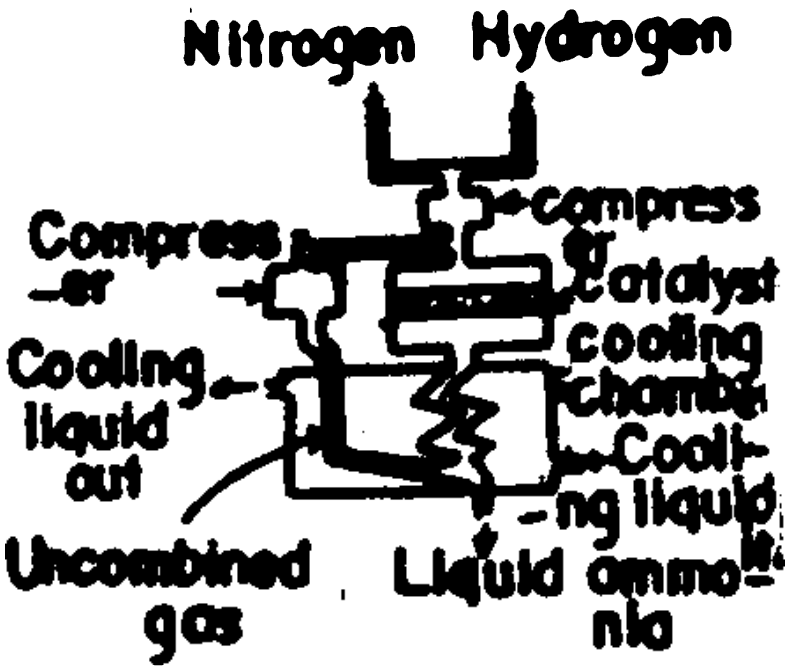


Fig.

This method used nitrogen and hydrogen in the ratio of 1:3 by volume is compressed to 500 atmosphere pressure and passed over finely divided catalyst at a temperature of 500° C. Then the following reaction takes place.

$$N_2(g) + 3H_2(g) \longrightarrow 2NH_2(g) + \text{Heat}$$

Molybdenum or alumina is used as a promotor in this reaction. The formation of Ammonia is reversible reaction. The formation of NH_3 is favoured by high pressure and low temperature. A moderate temperature of about 500°C gives the best yield of Ammonia. Ammonia being formed is continuously removed by liquifying it.

Properties of Ammonia

It is lighter than air. It is colourless. It possesses a characteristic pungent smell and it is highly soluble in water.

Ammonia is basic in nature. Ammonia gas turns in moist piece of red litmus paper to blue, showing that ammonia is basic or alkaline in nature.

Reaction with acids. Ammonia reacts with hydrochloric acid to form ammonium chloride.

$$NH_3\,(g) + HCL\,(aq) \longrightarrow NH_4Cl\,(s)$$

Ammonium chloride
(Dense white fumes)

This reaction is used as a test for ammonia gas.

$$NH_3 + H_2O \longrightarrow NH_4OH$$

With Oxygen. Ammonia burns in oxygen to give nitrogen and water.

$$4NH_3 + 3O_2 \longrightarrow 2N_2\ 6H_2O$$

With Chlorine. Ammonia reduces chlorine to form nitrogen and hydrogen chloride.

$$2NH_3 + 3Cl_2 \longrightarrow N_2 + 6HCl$$

With Water. Ammonia dissolves in water to give ammonium hydroxide.

Uses

As a refrigerating agent in ice-plant.

In the manufacture of various fertilizers. In the manufacture of nitric acid.

In household detergent. In the manufacture of artificial silk.

In solvay's process for the manufacture

of sodium carbonate and sodium bicarbonate.

Ammonia-water solution used for removing grease stains.

NITRIC ACID

Molecular formula is HNO_3. Relative molecular mass is 63.

Occurrence. Very small traces of nitric acid are found in the rainy water. In combined form, it occurs in nature in the form of its salts mainly potassium nitrate, KNO_3 and calcium nitrate $Ca(NO_3)_2$.

Preparation of Nitric acid. Nitric acid can be prepared in the laboratory by heating sodium nitrate with concentrated sulphuric acid in a glass retort. The vapours of nitric acid evolved are condensed as a light yellow liquid in a receiver cooled under tap water.

$$NaNO_3 + H_2SO_4 \xrightarrow{\text{heat}} HNO_3 + NaHSO_4$$

Properties of Nitric Acid. Pure nitric acid is colourless fuming and highly corrosive liquid. It harms the skin leaving yellow

Fig.

stains and soluble in water in all proportions and the solution has sour taste and turns blue litmus red. Pure nitric acid is unstable. It decomposes on heating.

$$4HNO_3(l) \xrightarrow{heat} 2H_2O + 4NO_2(g) + O_2(g)$$

Acidic properties. Nitric acid is a very strong acid. Like other acid it neutralizers bases forming salts and water.

$$NaOH(aq) + HNO_2(aq) \longrightarrow NaNO_3(aq) + H_2O(l)$$

Reactions. It reacts with basic oxides forming nitrates and water

$$CuO(s) + 2HNO_3(aq) \rightarrow Cu(NO_2)_3(aq) + H_2O(l)$$

It reacts with carbonate and bicarbonates liberating carbon dioxide.

$$Na_2CO_3(s) + 2HNO_3(aq) \longrightarrow 2NaNO_3(aq) + H_2O(l) + CO_2(g)$$

With Copper. With dil. nitric acid copper is oxidised to $Cu(NO_3)_2$, but HNO_3 is reduced to nitric oxide and water.

$$3Cu(s) + 8HNO_3(aq) \longrightarrow 3Cu(NO_3)_2(aq) + 4H_2O(l) + 2NO(g)$$

with conc. nitric acid copper is oxidized to copper (II) nitrate and nitric acid is reduced to nitrogen dioxide and water.

$$Cu(s) + 4HNO_3(aq) \longrightarrow Cu(NO_3)_2 + 2H_2O(l) + 2NO_2(g)$$

with zinc. A number of reduction products are formed

when Zn reacts with HNO_3

(1) $5Zn(s) + 12HNO_3(aq) \longrightarrow 5Zn(NO_3)_2(aq) + 6H_2O(l) + N_2(g)$

(2) $Zn(s) + 4HNO_2(aq) \longrightarrow$
$Zn(NO_3)_2(aq) + 2H_2O(l) + 2NO_2(g)$

(3) $3Zn(s) + 8HNO_3(aq) \longrightarrow$
$3Zn(NO_3)_2(aq) + 4H_2O(l) + 2NO(g)$

(4) $4Zn(s) + 10HNO_2(aq) \longrightarrow$
$4Zn(NO_3)_2(aq) + 5H_2O(l) + N_2O(g)$

With sulphur. Sulphur reacts with hot conc. HNO_2 to give dense fumes of nitrogen dioxide. Sulphur is oxidized to its oxyacid.

$S(s) + 6HNO_2(aq) \longrightarrow$
$H_2SO_4(aq) + 2H_2O(l) + 6NO(g)$

With phosphorus and iodine. Both phosphorus and iodine are oxidised to phosphoric acid and acidic acid.

$P(s) + 5HNO_3(aq) \longrightarrow$
$H_3PO_4(aq) + H_2O(l) + 5NO_2(g)$

$I_2(s)\ HNO_2(aq) \longrightarrow$
$2HIO_3(aq) + 10NO_2(g) + 4H_2O(l)$

With carbon. Hot conc. HNO_2 oxidizes carbon to CO_2.

$C(s) + 4HNO_3(aq) \longrightarrow$
$CO_2(g) + 2H_2O(l) + 4NO_2(g)$

Uses. It is used in the manufacture of fertilizers, dyes, plastics, textiles, drugs photographic films and synthetic fibres and for extraction of certain metals.

As a laboratory reagent and it refine of certain metals *e.g.* Ag and Au.

PHOSPHORUS

Occurrence. Rock phosphates and bones of animals are the main sources of phosphorus. As phosphor proteins, it is also present in eggs, milk, cheese and peas.

Symbol = P Relative atomic mass = 31 Molecular formula = P_4 Relative molecular mass = 124 Atomic number = 15 State = solid.

Position in periodic table. The phosphorus is placed in period 3 and group V A of the periodic table because it has five electrons in its valence shell.

Reaction with oxygen of air (burning). Ignition temperature of white phosphorus is very low (35°C), when white phosphorus is exposed to air it catches fire to give phosphorus pentaoxide.

$$P_4 + 5O_2 \longrightarrow 2P_2O_5 \text{ or } P_4O_{10}$$

with nitric acid. It reduces nitric acid to nitrogen dioxide and is itself oxidised to phosphoric acid.

$$P_4 + 20HNO_3 \rightarrow 4H_2PO_4 + 20NO_2 + 4H_2O$$

with chlorine. When phosphorus is put in jar of chlorine gas it burns at once to give phosphorus trichloride.

$$P_4 + 6Cl_2 \longrightarrow 4PCl_2$$

with caustic soda. White phosphorus dissolves in caustic soda on boiling in an inert atmosphere to give phosphine gas.

$$P_4 + 3NaOH + 3H_2O \rightarrow PH_3 + 3NaH_2PO_2$$

(Sodium hypo-phosphate)

Properties of white and red phosphorus

Property	*White phosphorus*	*Red phosphorous*
Solubility	Insoluble in water, soluble in CS_2 and other organic solvents	Insoluble in water and CS_2 and other organic solvents

State and colour	White waxy liquid	Purple-red amorphous powder
Density (g/cm^3)	1.8	2.2
Smell	Garlic-like	No smell
Melting point (K)	317	773-873 (under-pressure)
Storage	Under water	Can be stored easily
Toxicity	Poisonous	Non-poisonous
Ignition	Ignites at 308 K	Ignites at 530 K
Reac-tivity	Very reactive	Less reactive

Uses

It is used in the manufacture of phosphor-bronze which is an alloy of phosphorus-copper and tin.

Red phosphorus is used in match in-dustry.

It is used in fertilizer (Superphosphate a phosphorus compound).

It is used in the manufacturing of phosphoric acid

It is used in making smoke bombs.

It is also used in fire works.

Difference between oxygen and ozone

Oxygen	*Ozone*
Oxygen does not attack rubber.	Ozone attacks rubber.
Molecular formula O_2.	Molecular formula O_3.
Oxygen is quite reactive.	Ozone is much more reactive.
Heating has no effect on oxygen.	On heating ozone decomposes to form oxygen.
Oxygen is an oxidising agent.	Ozone is much stronger oxidising agent.

SULPHUR

Position in periodic table. The atomic number of sulphur is 16, so its electronic configuration is *k*(2), L(8) M(6). Sulphur has 6 valence electrons, so it has been placed in group VI just below oxygen.

Symbol = S Molecular formula = S_8
Atomic number = 16 Atomic mass = 32.1
Molecular mass = 256.8 State = Solid

Occurrence of sulphur. Sulphur is found around valcanoes in Japan, Sicily and America. Sulphur deposits are found at a depth of 150 to 500 meters below the surface of the earth in free state. In combined state it is found mostly as the metal sulphides, iron phyrites (FeS_2) galena (Pbs) etc.

Extraction of sulphur. Superheated steam and hot compressed air are forced into the underground deposits through pipes. The heat produced by steam melts the sulphur and the force of compressed air brings the water and molten sulphur to the surface where sulphur is cooled and solidified. This process is known as Frasch process.

Properties of Sulphur. Sulphur is a yellow solid at room temperature. It has no smell and is soluble in water but soluble in carbon disulphide.

Reaction with metals. Sulphur combines with metals giving sulphides on heating.

$$Fe(s) + S \longrightarrow FeS(s)$$

$$Mg(s) + S \longrightarrow MgS(s)$$

$$Zn(s) + S \longrightarrow ZnS(s)$$

With non metals. Various non metals that react with burning sulphur include bromine, chlorine, hydrogen, oxygen, etc.

$$S + 2Cl_2(g) \longrightarrow SCl_4(g)$$

$$S + O_2(g) \longrightarrow SO_2(g)$$

$$S + H_2(g) \longrightarrow H_2S(g)$$

With acids. Sulphur reacts with oxidizing acids.

$$S + 6HNO_3(aq) \longrightarrow 2H_2O(l)H_2SO_4(aq) + 6NO_2(g)$$

$$S + 2H_2SO_4(aq) \longrightarrow 2H_2O(l) + 3SO_2(g).$$

With alkalies. Sulphur reacts with hot conc. Solution of NaOH giving sulphides and sulphites.

Uses.

1. It is used in medicines especially for treatment of skin diseases.
2. It is used in the manufacture of gun powder, matches and fire works.
3. It is also used in the manufacture of sulphur dyes which are cheap and fast.
4. It is also used in the vulcanization of rubber.

HYDROGEN SULPHIDE

Occurrence. Small amount of hydrogen sulphide gas are present in air. Hydrogen sulphide is formed by the decomposition of plants and animals having sulphur containing proteins. Some mineral water also contains sulphur.

Molecular formula is H_2S Density is 1.538 Relative molecular mass is 34.1 solubility is 1.97 volumes.

Preparation of Hydrogen sulphide. In the laboratory, hydrogen sulphide can be prepared by the action of dilute sulphuric acid on ferrous sulphide.

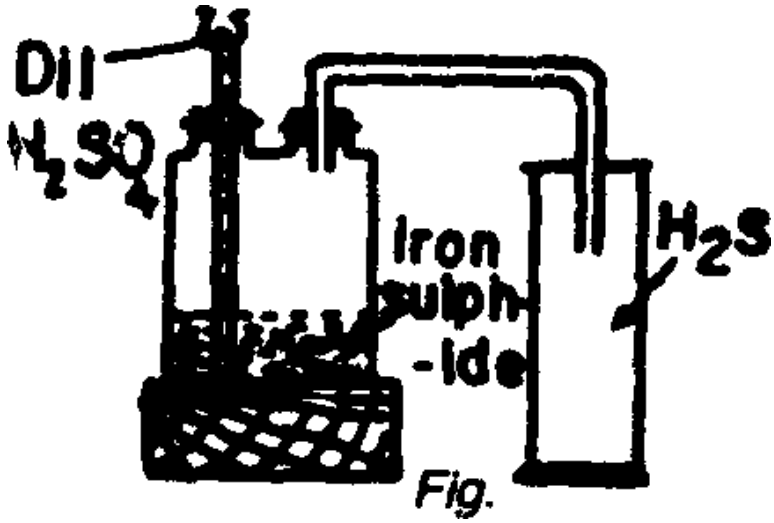


Fig.

$$FeS(s) + H_2SO_4(aq) \longrightarrow FeSO_4(aq) + H_2S(g)$$

Properties of Hydrogen sulphide. $H_2S(g)$ gas is a colourless gas. It is heavier than air and soluble in water. It has foul smell resembling that of damped eggs. H_2S gas ionizes in water to give hydrogen ions and sulphide ions.

Reaction with alkalies. H_2S is a weak acid so it reacts with alkalie to form salt and water.

$$H_2S + 2NaOH \longrightarrow Na2S + 2H_2O$$

(sodium sulphide)

Reaction with sulphuric acid. When H_2S reduces conc. H_2SO_4 to sulphur dioxide and is itself oxidises to sulphur

$$H_2SO_4 + H_2S \longrightarrow 2H_2O + SO_2 + S$$

(white ppt.)

Reaction with copper sulphate. When H_2S is passed through $CuSO_4$ solution then a black precipitate of copper sulphide is formed.

$$CuSO_4(aq) + H_2S(g) \rightarrow CuS(s) + H_2SO_4(aq)$$

(Copper sulphate) (Copper sulphide)

Combustibility. It is not a supporter of combustion but itself burns in air with a pale blue flame.

$$2H_2S\,(g) + 3O_2(g) \longrightarrow 2H_2O(g) + 2SO_2(g)$$

In limited supply of air

$$2H_2S + O_2 \longrightarrow 2H_2O + 2S$$

Uses. This is used as a reducing agent and as laboratory reagent in the identification of certain metal ions *e.g.*, Cu^{2+}, Pb^{2+}, Od^{2+} etc.

It is also used in many paints and pigments.

SULPHUR DIOXIDE

In the laboratory, sulphur dioxide gas is prepared by heating copper turning with concentrated sulphuric acid. This reaction takes place—

$$Cu + 2H_2SO_4 \xrightarrow{\text{heat}} CuSO_4 + 2H_2O + SO_2\uparrow$$
(conc.)

In this reaction sulphuric acid is reduced to sulphur dioxide by copper metal.

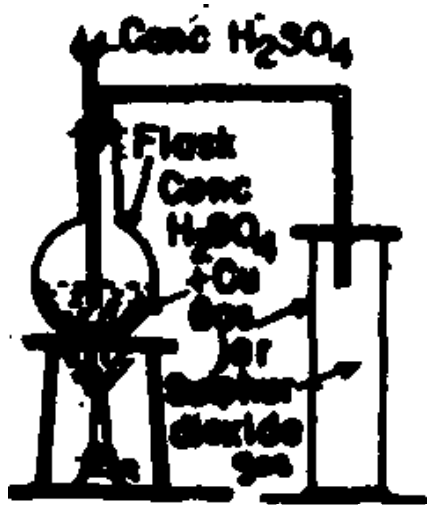


Fig.

Sulphur dioxide gas can also be prepared in the laboratory by adding sulphuric acid to sodium sulphite then no heating is required.

Molecular Formula is SO_2, **Density** is 2.923, **Relative molecular mass** is 64, **Solubility** is 27.3 volume.

Properties. Sulphur dioxide is a colourless, pungent smelling gas. It is denser than air. Sulphur dioxide is soluble in water it forms a strong acidic solution.

Sulphur dioxide is acidic in nature. When sulphur dioxide is dissolved in water sulphurous acid is formed.

$$SO_2 + H_2O \longrightarrow H_2SO_3$$

(4) **Reaction** with hydrogen sulphide. Sulphur dioxide oxidises hydrogen sulphide to sulphur.

$$2H_2S + SO_2 \longrightarrow 2H_2O + 3S \text{ (Sulphur)}$$

With Nitric acid. Sulphur dioxide reduces concentrated nitric acid to nitrogen dioxide.

$$2HNO_3 + SO_2 \longrightarrow 2NO_2 + H_2SO_4$$

Reduction of potassium permanganate and potassium dichromate. Sulphur dioxide reduces permanganate solution to manganese sulphate and potassium dichromate solution to chromium sulphate.

$$2KMnO_4 + 5SO_2 + 2H_2O \longrightarrow K_2SO_4 + 2MnSO_4 + 2H_2SO_4$$

$$K_2Cr_2O_7 + 3SO_2 + H_2SO_4 \longrightarrow K_2SO_4 + Cr_2(SO_4)_3 + H_2O$$

Reaction with chlorine. Sulphur dioxide reduces chlorine to hydrochloric acid

$$Cl_2 + SO_2 + 2H_2O \longrightarrow 2HCl + H_2SO_4$$

Sulphur dioxide neither burns nor supports combustion.

Uses. Sulphur dioxide is used for manufacture of sulphuric acid. It is used for bleaching wool, silk, paper etc. It is used as disinfectant. It is used as dry fruits preservative.

CHLORINE

Atomic number is 17, Symbol is Cl, **Molecular formula** is Cl_2, **Atomic mass** is 35.5, State is Gas, **Molecular Mass** is 71.0.

Position in the periodic table. The electronic arrangement 2, 8, 7 in chlorine atom has placed in group VIIA of the periodic table. It belongs to 3rd period of the periodic table as the number of its valence shell is 7 [K(2), M(8), L(7)].

Occurrence. Because of its high reactivity it does not occur free in nature. It is found as metal chlorides, sodium chloride in rocks and sea water.

Preparation. By heating a mixture of magnese dioxide and concentrated hydrochloric acid.

$$MnO_2(s) + 4HCl(aq) \xrightarrow{heat} MnCl_2(aq) + 2H_2O(l) + Cl_2(g)$$

BROMINE

Bromine is prepared by heating a mixture of sodium bromide, magnese dioxide and conc.

$$H_2SO_4\ 2NaBr + MnO_2 + 2H_2SO_4 \longrightarrow Na_2SO_4 + MnSO_4 + 2H_2O + Br_2$$

(Bromine)

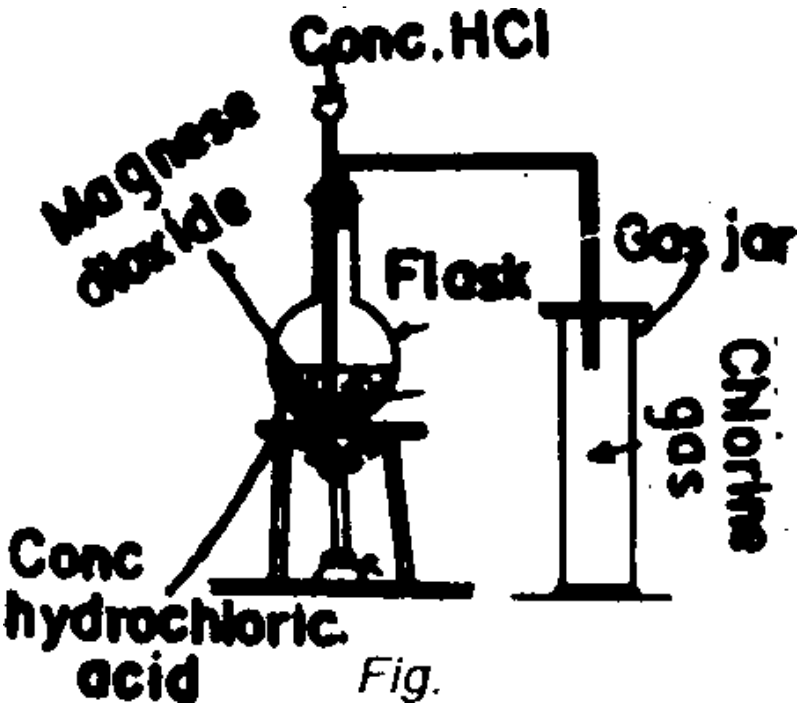


Fig.

Uses. It is used to prepare insecticides such as D.D.T. and is also used for making bleaching powder. It is also used in preparation of large number of organic compounds lie chloroform and carbon-tetrachloride. It is helpful for making plastic polynimyl chloride (PVC).

Properties

Chlorine is a greenish-yellow gas having initating smell. It is heavier than air. It is moderately soluble in water. It does not burn but supports combustion.

Reaction with alkalies. Chlorine reacts with cold dilute solution of sodium hydroxide to form a mixture of chloride and hypochlorite.

$$2NaOH(aq) + Cl_2(g) \longrightarrow$$

$$NaCl(aq) + NaOCl(aq) + H_2O(l)H_2O(l)$$

Sodium Hypochlorite

With Sodium. Hot sodium burns in chlorine to form sodium chloride (white fumes)

$$2Na + Cl_2 \rightarrow 2NaCl$$

With hydrogen sulphide. Chlorine oxidises hydrogen sulphide to sulphur i.e.

$$H_2S(aq) + Cl_2(g) \longrightarrow 2HCl(aq) + S(s)$$

An oxidising agent. Chlorine oxidises Ferrous chloride to ferric chloride-i.e.

$$2FeCl_2(aq) + Cl_2(g) \longrightarrow 2FeCl_3(aq)$$

Iron (II) chloride Iron (III) chloride

Comparison of Bleaching action of SO_2 and Cl_2

Sulphur dioxide	*Chlorine*
Bleaching action of SO_2 is due to its reduction nature.	Bleaching action of Cl_2 is due to its oxidising nature.
$SO_2 + 2H_2O \longrightarrow H_2SO_4 + 2H$	$Cl_2 + H_2O \longrightarrow HCl + HClO$ $HClO \longrightarrow HCl + O$
Bleaching is temporary.	Bleaching is permanent.
It acts as mild bleaching agent.	It is a strong bleaching agent.

Hydrogen Chloride

Hydrogen Chloride gas is prepared in the laboratory by heating sodium chloride (common salt) with concentrated sulphuric acid.

$$NaCl(s) + H_2SO_4(aq) \xrightarrow{\text{heat}} NaHSO_4(aq) + HCl(g)$$

Sodium hydrogen Sulphate

$$NaHSO_4(aq) + NaCl(s) \longrightarrow Na_2SO_{41}(aq) + HCl(g)$$

Its molecular formula is HCl and molecular mass is 36.5.

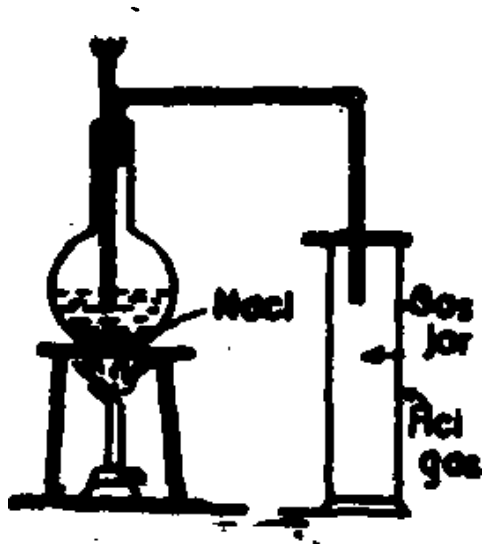


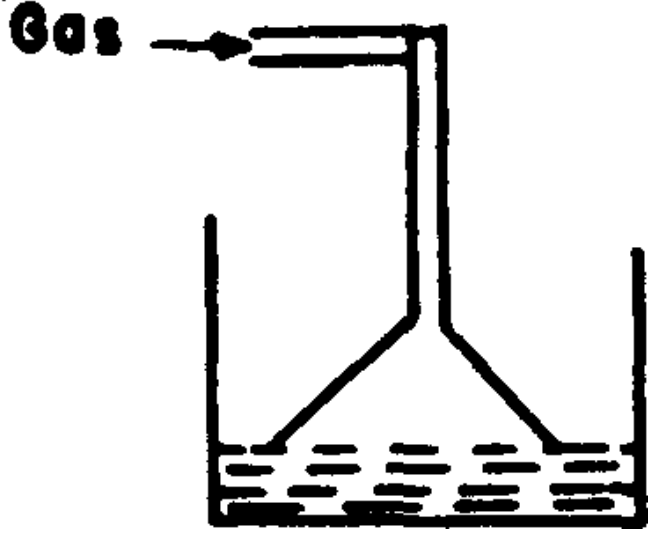
Fig.

Preparation of Hydrochorlic acid. HCl can be obtained by dissolving hydrochloric gas into water.

Properties

Hydrogen Chloride colourless gas with pungent smell. Pure Hydrochloric acid is also

colourless but due to iron impurity it becomes light yellow. It is heavier than air, and it is hightly soluble in water.



Funnel Method

Fig.

Hydrochloric acid decomposes carbonates into bicarbonates with the evolution of carbon dioxide-

$Na_2CO_3(s) + 2HCl(aq) \longrightarrow$

Sodium carbonate

$2NaCl(aq) + H_2O(l) + CO_2(g)$

Combustibility. Hydrogen chloride gas is neither combustible nor a supporter of combustion.

Hydrochloric acid reacts with all the basic

oxides and hydroxides forming salt and water

$CaO(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l)$

$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$

$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$

Action with nitric acid. A mixture of there parts by volume of conc. HCl and one part of conc. HNO_3 is known as aqua regia. Aqua regia is a very strong acid capable of dissolving even noble metals like gold, platinum etc.

Some of the metals dissolve is hydrochloric acid with evolution of hydrogen gas and formation of corresponding salts.

Uses of hydrochloric acid. It is used to clean metal surfaces before electroplating.

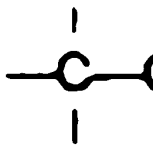
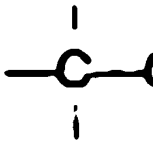
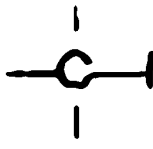
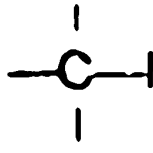
It is used in the manufacture of chlorine.

It is used in textile factories for dyeing and also in tanning industries.

In laboratory it is used as a reagent.

Functional group. To decide the properties of a compound and to distinguishes it from other 'functional group' has

been devised. For example, –Cl is chloro group. It decides the properties of the chloro derivatives of alkanes, or OH is an alcoholic group, it decides the properties of alcohol. Some functional groups are

Group	*Name*	
	Chloro	CH_3Cl, C_2H_5Cl, C_3H_7C
	Alcoholic	CH_3OH, CH_3CH_3OH
	Amino	CH_3NH_2, $CH_3CH_2NH_2$
	Nitro	CH_3NO_2, $CH_3CH_2NH_2$
—CHO	Aldehyde	HCHO, CH_3CHO

—COOH	Carbo-xylic	$HCOOH$, $CH_3CH_2NH_2$
—COOR	Ester	CH_3COOCH_3, $CH_3COOC_2H_5$

The chemical properties of the compounds containing same functional group are similar. For example, methyl alcohol and ethyl alcohol have the similar chemical properties.

The physical and chemical properties of compounds containing different functional groups are different.

A homologous series of compounds containing each type of functional group exists. For example, homologous series of alcohols like CH_3OH, $CH_{33}CH_2OH$ etc.

Advantages. By this system the identification of all the compounds containing a particular group becomes easy.

If the presence of the functional group is identified nature of a newly synthesised compound can be established

The study of large number of known organic compounds becomes systematic and the compounds are classified according to the nature and type of groups.

Fermentation. is a slow decomposition process in which complex organic compounds break into simpler compounds in presence of enzyme catalysts, i.e. sowing of milk, curd from oil.

Ethyl alcohol (Ethanol). Fermentation is used for the industrial preparation of ethyl alcohol from molasses which is a by-product of the sugar industry.

$$C_{12}H_{22}O_{11} + H_2O \xrightarrow[\text{invertose}]{\text{yeast}} C_6H_{12}O_6 + C_6H_{12}O_6$$

glucose fructose

$$C_6H_{12}O_6 \xrightarrow[\text{(zymase)}]{\text{yeast}} 2C_2H_5OH + 2CO_2(g)$$

Action of acids (Esterfication). On treatment with acids in the presence of a

dehydrating agents like $ZnCl_2$ $P_2O_5H_2SO_4$ esters are formed.

$$C_2H_5OH + CH_3COOH \xrightarrow{H_2SO_4} CH_3COOC_2H_5 + H_2O$$

Ethyl acetate

Action of sodium Sodium displaces hydrogen atom of —OH (hydroxyl) group.

$$2C_2H_5OH + 2Na \longrightarrow 2C_2H_5ONa + H_2$$

(sodium ethoxide)

Action of phosphorus halides

$$C_2H_5OH + PCl_5 \longrightarrow C_2H_5Cl + POCl_3 + HCl$$

Oxidation

$$C_2H_5OH + 2(O) \xrightarrow[H_2SO_4]{K_2Cr_2O_7+} (\text{Acetic acid})\ CH_2COOH + H_2O$$

Ethyl alcohol is oxidised to acetic acid in this reaction. The mixture of potassium dichromate and sulphuric acid is a strong oxidising agent. On passing ethyl alcohol vapours over heated copper, acetaldehyde

and hydrogen are formed.

$$C_2H_5OH \xrightarrow{Cu\,300^\circ C} CH_3CHO + H_2.$$

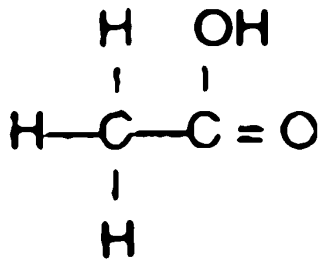
Uses of ethyl alcohol. It is used for preparing power alcohol which is a fuel in automobiles. It is an essential constituent of alcoholic drinks (i.e., whisky, rum, wine, etc.). It is used for the preparation of organic compounds as ether, chloroform, dyes, and as a preservative of biological specimens and an antiseptic for skin.

The term alcohol refers to ethyl alcohol. It is an intoxicant and if consumed by a person and it may harm him. Under the influence of alcohol, person becomes incapable to decide good and bad. Due to adulteration if a person takes methanol instead of ethanol, he may lose his eye sight.

ACETIC ACID

Molecular formula. $C_3H_4O_2$, Common formula. CH_3COOH

Structural formula.



Preparation. Acetic acid may be prepared in the laboratory by oxidation of ethyl alcohol with a strong oxidising agent like potassium dichromate and sulphuric acid.

$$CH_3CH_2OH + 2[O] \xrightarrow{K_2Cr_2O_7 + H_2SO_4} CH_3COOH + H_2O$$

(acetic acid)

Acetic acid. Is a colourless liquid. It has vinegar odour and sour taste. It boils at 118° C. Its vapours are suffocating and cause damage to the lungs.

Acetic acid changes the wet blue litmus paper to red, and it is miscible with alcohol, water, acetone etc in all proportions.

Action with Sodium Carbonate. Effervescene of CO_2 is produced when acetic acid solution is added to a solution of sodium.

$CH_3COOH + Na_2CO_3 \longrightarrow$
Acetic acid Sodium Carbonate

$2CH_3COONa + CO + H_2O$
Sodium acetate

Acetic acid is neutralised by the ammonia solution.

$CH_3COOH + NH_4OH \longrightarrow$
Acetic Acid Ammonium hydroxide

$CH_3COONH_4 + H_2O$
Ammonium acetate Water

When acetic acid is heated with zinc or sodium metal, H_2 gas is produced.

$2CH_3COOH + Zn \longrightarrow$

$CH_3(COO)_2Zn + H_2(g)$

When acetic acid is treated with excess of bromine then tribromoacetic acid is produced.

$$CH_3COOH \xrightarrow{Br_2} CH_2BrCOOH \xrightarrow{Br_2} CHBr_2COOH \xrightarrow{Br_2} CBr_3COOH_3$$

Acetic acid neutralises a solution of sodium hydroxide.

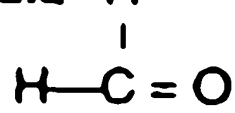
$CH_3COOH + NaOH \longrightarrow CH_3COONa + H_2O$

Uses. It is used in preparing esters and for manufacturing dyes. Acetic acid is also used to coagulate rubber from the latex.

FORMALDEHYDE

Molecular formula CH_2O

Structural formula



It is prepared by the oxidation of methyl alcohol (CH_3OH)

$$CH_3OH + [O] \xrightarrow[200 - 300°C]{Pt + Asbestor} HCHO + H_2O$$

Methyld alcohol formaldehyde

Properties of formaldehyde

(1) It is a colourless gas has irritating odour an condenses very easily. It is highly soluble in water.

Reaction with Ammonia. It forms a complex compound with ammonia

$$6HCHO + 4NH_3 \longrightarrow (CH_2)_6N_4 + 6H_2O$$

Hexamethylene tetramine

Reaction with sodium hydroxide. Formaldehyde reacts with conc. solution of sodium hydroxide and forms methanol and sodium formate.

$$\underset{\text{formaldehyde}}{2HCHO} + \underset{\text{sodium hydroxide}}{NaOH} \longrightarrow \underset{\text{methanol}}{CH_3COH} + \underset{\text{sodium formate}}{HCOONa}$$

This reaction is known as Cannizaro's Reaction.

Condensation with phenol. Formaldehyde condenses with phenol to form a synthetic plastic called Bakelite.

Polymerization. When aqueous solution of formaldehyde (formalin) is evaporated to dryness, a crystalline solid known as paraformaldehyde is formed.

$$\underset{\text{formaldehyde}}{nHCHO} \longrightarrow \underset{\text{paraformaldehyde}}{(HCHO)_n}$$

(m.p.t. 123° C.

Uses. It is used in the manufacture of urinary antiseptt urotropine.

It is used as antiseptic and disinfectant.

It is also used in the manufacture of synthetic dyes like pararosaline and indigo.

ALKALI METALS

Alkali metals. The elements of group IA, Lithium (Li), Sodium (Na), Rubidium (Rb), Potassium (K), Caesium (Cs) and Francium (Fr) are called alkali metals because their hydroxides give strongly alkaline solutions *e.g.* NaOH, KOH etc.

Electronic configuration of alkali metals

Name	Symbol (*with atomic weight*)	*Electronic configuration*
Francium	Fr_{87}	$1s^2, 2p^2 2p^6 3s^2 3p^6 3d^{10}, 4s^2 4p^6, 4d^{10} 4f^{14}, 5s^2 5p^6 5d^{10}, 6s^2 6p^6, 7s^1$

Lithium	Li_3	$1s^2, 2s^1$
Sodium	Na_{11}	$1s^2, 2s^2, 2p^6, 3s^1$
Potassium	K_{19}	$1s^2, 2s^2 2p^6, 3s^2 3p^6, 4s^1$
Rubidium	Rb_{37}	$1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^{10}, 4s^2 4p^6, 5s^1$
Caesium	Cs_{55}	$1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^{10}, 4s^2 4p^6, 4d^{10}, 5s^2 5p^6, 6s^1$

Alkali metal have one electron in their outer most orbit (ns^1)

Physical properties of alkali metals

Element	*Atomic size A*	*m.p. (k)*	*Density (g/cm^3)*	*Ionization energy (kJ mol)*	*electronegativity*

Fr	—	—	—	—	—
Li	1.52	453.5	0.54	520	1.0
Na	1.86	370.8	0.97	495	0.9
K	2.27	336.7	0.86	418	0.8
Rb	2.48	312.0	1.53	403	0.8
Cs	2.65	301.6	1.87	374	0.7

They are silvery white in colour, soft and light metals and have one electron in the outermost shell (ms^{-1}).

Their ionization energies are very very low and decreases in the group from Li to Fr.

Their densities are low

They form monovalent cations e.g. Li^+,Na^+. Their salts are soluble in water and it impart characteristic colour to the flame.

Chemical properties. They are strong reducing agent react with almost all non-metals. Their hydroxides give alkaline solutions. Their oxides, halides, nitrates,

hydrides, hydroxides etc. give similar reactions. They react vigorously with water and other compounds containing acidic hydrogen.

Some important ores of (a) Lithium (b) Potassium (c) Sodium:

(a) **Sodium**

(i) Common salt: Nacl

(ii) Chile salt petre: $NaNO_3$

(iii) Soda ash: Na_2CO_3

(b) **Lithium**

(i) Lepidolite: $Li_2 (F,OH)_2 Al_2 (SiO_2)_2$

(ii) Petalite: $LiAl (Si_2O_5)_2$

(iii) Triphylite: $(Li,Na)_2 PO_4 (Fe,Mn)_3 (PO_4)_5$

(c) **Potassium**

(i) Potassium chloride: KCl

(ii) Carnalite: KCl, $MgCl_2 6H_2O$

(iii) Felspar: $K_2O. Al_2O_3 6SiO_2$

Uses of Alkali Metals

(a) Sodium (i) as a reagent in organic analysis and synthesis (ii) in sodium vapour

lamp (iii) as a reducing agent in extraction of boron and silicon (iv) in nuclear reactor as a heat carrier (good conductor of heat).

(b) Lithium (i) In making a special variety of glass which is very strong and resists weather. (ii) In television picture tubes (iii) in medicine as lithium citrate (iv) in air-conditioning plants a lithium chloride

(c) **Potassium** (i) in photoelectric cells (ii) its alloy with sodium is used for measuring high temperatures, such as furnaces.

(d) **Rudidium** along with Caesium is used in the manufacture of radio-tubes and photoelectric cells.

Alkali metals, are usually isolated by the electrolysis of their fused salts.

Extraction of sodium by electrolysis of fused sodium chloride by down's cell method.

Manufacture of Sodium. Sodium metal is repaired by the electrolytic dissociation of molten sodium chloride. Down's electrolytic cell is used for this rises a circular carbon anode. The anode is surrounded by a ring

shaped iron cathode enclosed in a wire gauge shell which also acts as partition and separates the electrolyte. Then Sodium chloride is mixed with sodium carbonate and melted in the iron tank. By passing electric current. Sodium chloride gets electrolysed producing sodium metal at the cathode the chlorine gas at the anode. Sodium metal collects at the cathode and goes into the reservoir through pipe and then Chlorine is taken out through the tube.

SODIUM CARBONATE (Na_2CO_3)

Now a days sodium carbonate is manufactured on large scale by solvay ammonia process following steps. Carbon dioxide is passed through a concentrated solution of (brine) sodium chloride (NaCl) saturated with ammonia and upon reaction, sodium bicarbonate ($NaHCO_3$) gets precipitated because of its low solubility in water.

$$NH_3(g) + H_2O(l) + CO_2(g) \longrightarrow NH_4HCO_2(aq)$$

Ammonium bicarbonate

$$NH_4HCO_3(aq) + NaCl(aq) \longrightarrow NH_4Cl(aq) + NaHCO_3(s)$$

(Sodium bicarbonate)

Sodium bicarbonate is obtained as a white crystalline solid by filteration and is well washed so as to free from ammonium compound. Thus separated sodium bicarbonate is heated to convert it into sodium carbonate.

$$2NaHCO_3(s) \xrightarrow{\text{heat}} Na_2CO_3(s) + H_2O(l) + CO_2(g)$$

Ammonium chloride and carbon dioxide are used again and again and so the manufacture of sodium carbonate involves only sodium chloride as the cheap raw material.

When anahydrous it melts at 852° C. This dissolved in water with evolution of heat. Its aqueous solution is alkaline due to hydrolysis and its solutions turn red litmus blue

$$Na_2CO_3(s) + H_2O(l) \longrightarrow 2NaOH(aq) + CO_2(g)$$

Upon cooling its hot concentrated solution this gives $NaCO_3 \cdot 10H_2O$ (decahydrate). When this is exposed to air, it efforesces and finally changes into monohydrate $Na_2CO_3 \cdot H_2O$.

Upon strong heating, this changes into an hydrous. This reacts with minerals acids to give carbon dioxide gas.

$$Na_2CO_3(s) + 2HCl(aq) \longrightarrow 2NaCl(s) + CO_3(g) + H_2O(l)$$

Uses. It is used in the manufacture of glass, soap powder. Used as a washing soda and in the softening of water. It is used as a base in acid base titration.

Preparation of Potassium carbonate. Potassium carbonate is prepared by passing CO_2 into a suspension of $MgCO_2$ in a solution of KCl when sparingly soluble double salt $KHCO_2$, $MgCO_2\ 4H_2O$ precipitates out

$$MgCO_3 + 3H_2O + CO_2 \longrightarrow Mg(HCO_3)_2 + 2H_2O$$

$$2KCl + Mg(HCO_3)_2 \longrightarrow 2KHCO_3 + MgCl_2$$

$$KHCO_3 + MgCO_3 + 4H_2O \longrightarrow$$

$KHCO_3\ MgCO_3\ 4H_2O$.

This double salt is heated with water under pressure when soluble KCO_3 goes into solution and insoluble $MgCO_3$ is separated on concentration, potassium carbonate crystallize out.

$$2KHCO_3\ MgCO_3\ 4H_2O \longrightarrow 2MgCO_3 + K_2CO_3 + 9H_2O + CO_2$$

Uses. It is used to the manufacture soft soap. As a constituent of fusion mixture ($Na_2CO_3 + K_2CO_3$). In the manufacture of caustic potash KOH.

Preparation of sodium cyanide. From Sodamide. In this method sodium is heated in covered iron pots through which ammonia is passed. The following reaction take place.

First sodamide is formed

$$(2NH_3 + 2Na \longrightarrow 2NaNH_2 + H_2)$$

and sodamide on reaction with carbon gives sodium cynamide

$$2NaNH_2 + C \longrightarrow Na_2NCN + 2H_2.$$

Sodium cynamide on further reaction with carbon gives sodiumcyanide

$$Na_2NCN + C \longrightarrow 2NaCN$$

Properties. It is a colourless, crystalline substance with the odour of hydrogen cyanide, is highly poisonous and very soluble in water. Forms soluble complex cyanides with salts of transition metals like Cu, Ag, Au, Zn etc.

$$4Ag + 8NaCN + 2H_2O + O_2 \longrightarrow 4Na[Ag(CN_2)] + 4NaOH$$

Sod. argento cyanide

Uses. It is used in the extraction of silver and gold, in electroplating photography and as germicide.

Potassium cyanide (KCN) is prepared by heating potassium ferrocyanide with potassium metal.

$$K_4Fe(CN)_6 + 2K \longrightarrow 6KCN + Fe$$

or by passing ammonia over fused potassium carbonate containing carbon

$$K_2CO_3 + 4C + 2NH_3(g) \longrightarrow 2KCN + 3CO(g) + 3H_2(g)$$

Properties. It is a white crystalline solid, highly soluble in water. It is the most deadly poisonous.

Uses. It is used in electroplating and in the extraction of metals such as gold, silver.

Preparation of Potassium chloride. This is extracted from carnallite $KCl.MgCl_2.6H_2O$) by boiling with 20% magnesium chloride solution. Carnallite dissolves leaving other impurities undissolved. They are filtered off and the solution is crystallized when pottassium chloride separates as cubic crystals leaving magnesium chloride in the mother liquor.

Uses. It is used as a fertilizer, and to patients with high blood pressure use potassium chloride in place of common salt.

Preparation of Potassium hydroxide. It is prepared by the electrolysis of Potassium chloride solution,

$$KCl \quad K^+ + Cl^-$$

At cathode $K^- + e \longrightarrow K$

At anode $Cl^- e \longrightarrow Cl$

$$Cl + Cl \longrightarrow Cl_2$$

$$2K + 2H_2O \longrightarrow 2KOH + H_2$$

It can also be prepared by the action of barium hydroxide on Potassium sulphate.

$$Ba(OH)_2 + K_2SO_4 \longrightarrow BaSO_4(s) + 2KOH$$

Properties. It is highly soluble in water, and its aqueous solution behaves as a strong base. It reacts with Cl_2

Cold and dilute. $2KOH + Cl_2 \longrightarrow KCl + KClO + H_2O$

Hot and conc. $6KOH + 3Cl_2 \longrightarrow 5KCl + KClO_3 + 3H_2O$

It absorbs CO_2. $2KOH + CO_2 \longrightarrow K_2CO_3 + H_2O$

Uses. It is used in the manufacture of toilet soaps and as an electrolyte in nickel-iron storage batteries.

Preparation of sodium chloride. Generally the salt is made by the evaporation of sea water by the sun's heat. Some salt is also found from mines by dissolving in water and then pumping out the salt solution so formed.

Salt obtained by evaporation has impurities. Common salt is dissolved in a minimum quantity of water to get saturated solution. Insoluble impurities are filtered off. HCl gas is passed through the solution. Due to common ion effect ionic product rises above the solubility product of sodium chloride which is thrown out as pure crystals. The impurities being more soluble, remain in the mother liquor. After this the crystals are filtered, washed and dried.

Properties. It is a colourless crystalline solid and is soluble in water. It is insoluble in organic solvents such as benzene, alcohol. It melts at 1074 K.

Uses. It is used as a food article. As a preservative e.g., in packing of meat when mixed with ice, it gives freezing mixture.

ALKALINE EARTH METALS

Beryllium, magnesium, calcium, Barium and radium constitute group IIA of the periodic table are known as a alkaline earth metals.

Electronic configurations of alkaline earth metals

Element	At. No.	*Electronic configuration*
Ba	56	[Xe] $6s^2$
Be	4	[He] $2s^2$
Mg	12	[Ne] $3s^2$
Ca	20	[Ar] $4s^2$
Sr	38	[Kr] $5s^2$
Ra	88	[Rn] $7s^2$

Physical characteristics. Atomic sizes are smaller than those of alkali metals but larger than any other element of the same period.

Their valency shell configuration is ns^2, therefore all these elements tend to attain the core electronic configuration of the noble gas by loss of two electrons.

Their first ionization energies are higher than those of the corresponding metals be-

cause of their smaller size. They form ionic, colourless crystalline salts of the bivalent cations.

They are electropositive metals but less electropositive than alkali metals and their electropositive character increases with the atomic mass.

Chemical characteristics. They form basic oxides and decompose water, under suitable conditions, evolving hydrogen.

Their carbonates are insoluble in water and on heating decompose to oxides and carbon dioxide.

Halides of Beryllium are covalents compounds only are bad conductors of electricity in molten state. The halides of other metals are ionic solids. They are good conductors of electricity in fused as well as in the dissolved state.

All the alkaline earth metal burn in oxygen forming oxides. Beryllium, magnesium and calcium form monoxide while strontium and barium form peroxides SrO_2 and BaO_2.

The vigorously decompose dilute acids with the evolution of hydrogen.

Beryllium halides have covalent character and dissolves in organic solvent.

Beryllium sulphate is soluble in water while those of Ca, Ba, Sr are insoluble in water.

Beryllium salt do not impart colour to the flame those of Ca, Ba, Sr impart colours to flame.

Its carbonate is not precipitated by ammonium carbonate in presence of ammonium chloride.

Ores of beryllium.

(i) Beryl—$3BeO.Al_2O_3.6S_1O_2$

(ii) Chrysoberyl—$BeOAl_2O_3$

(iii) Phenacite—Be_2SiO_4

Ores of radium

(i) Pitch blende—ore of uranium and contains in it radium.

(ii) Carnotite—a sand stone impregnated with high percentage of radium.

Ores of magnesium.

(i) Magnesite— $MgCO_2$

(ii) Dolomite—$MgCO_3CaCO_3$

(iii) Epsom salt—$MgSO_4 7H_2O$

(iv) Chamallite—$MgCl_2KCl\ 6H_2O$

(v) Asbestos—$CaSiO_3\ 2MgSiO_3$

Ores of calcium

(i) Lime stone (marble)— $CaCO_3$

(ii) Dolomite— $CaCO_3MgCO_3$

Ores of strontium.

(i) Strontionite— $SrCO_2$

(ii) Celestine $SrSO_4$

Ores of Barium

(i) Witherite $BaCO_2$

(ii) Barytes— $BaSO_4$

Extraction of alkaline earth metals

Magnesium is extracted by electrolysis of a fused mixture of anhydrous magnesium chloride and sodium chloride in the ratio of 7:3 in an iron vessel (which serves as cathode) containing a graphite rod (which

acts as anode). The graphite rod is surrounded by a porcelain tube, through which the liberated chlorine gas escapes out and hence does not come in contact with magnesium. The temperature of the vessel is maintained at 970K.

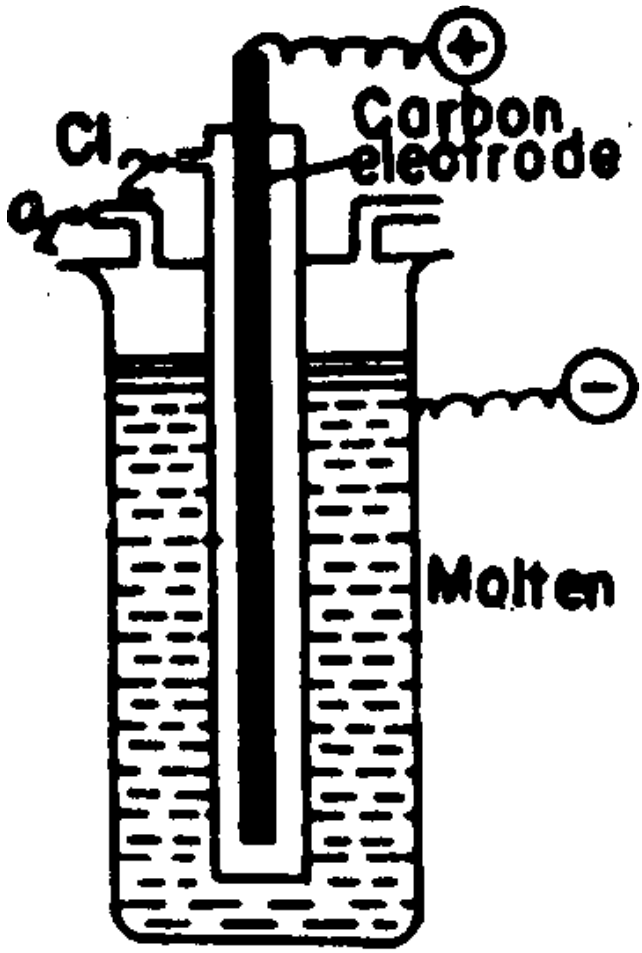


Fig.

At cathode: $Mg^{2+} + 2e \longrightarrow Mg$

At anode: $2Cl^- - 2e \longrightarrow Cl_2$

Molten magnesium being lighter than the molten electrolyte rises and floats at the surface. It is periodically removed with perforated ladles.

To avoid the oxidation of molten magnesium, the electrolysis is carried out in an inert atmosphere of coal gas.

Uses of magnesium. In the preparation of alloys. In the preparation of magnesium wire, ribbon and flash light powders which are used in photography and fire works. For developing high vacuum in radio valves.

Calcium is extracted by the electrolysis of a fused mixture of calcium fluoride and calcium chloride in the ratio of 1.6:10 in an iron crucible, lined inside with graphite which also serves as anode. Cathode is a hollow tube or iron, which is water cooled. The cathode can be moved up and down with the help of screw.

During electrolysis, calcium is deposited on the cathode.

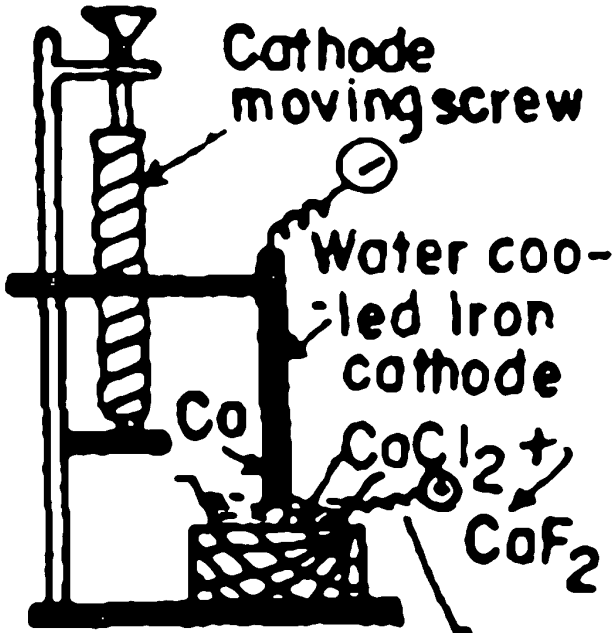


Fig.

As the metal accumulates, the cathode is raised. The calcium metal is obtained as a rod. The lower end of it is dipped in the fused melt and acts as cathode.

At cathode: $Ca^{2+} + 2e^- \longrightarrow Ca$

At anode: $2Cl^- - 2e^- \longrightarrow Cl_2$

Chlorine is obtained as by product.

Uses of calcium. It is a powerful reducing agent It is used in the extraction of chromium, thorium and beryllium metals from their oxide When alloyed with lead it is used as a cable cover. It is used to remove

last traces of air from vacuum tubes because it reacts with O_2 and N_2 at high temperatures.

Barium and strontium may be obtained by reduction of their oxides with Aluminium at 1500K.

$$3BaO + 2Al \longrightarrow Al_2O_2 + 3Ba$$

$$3SrO + 2Al \longrightarrow Al_2O_3 + 3Sr$$

Radium is extracted by the electrolysis of fused radium chloride using mercury cathode, when radium-mercury amalgam is produced. Radium is then obtained by distiling off mercury.

Uses of Barium. (i) For removing air from vacuum tubes.

(ii) As a reducing agent.

Uses of radium. (i) In the treatment of cancer.

(ii) In the manufacture of luminous paints.

Magnesium oxide MgO is prepared either by burning magnesium in air or calcining natural magnesite ($MgCO_3$) in a kiln.

$$2Mg + O_2 \longrightarrow 2MgO$$

$$MgCO_2 \longrightarrow MgO + CO_2$$

Uses. Because of its very high melting point it is used in manufacturing infusible crucible, fire bricks. Mixed with asbestos powder it gives fluffy powder and is used for heat lagging of steam pipes and boilers. It is also used in medicine as purgative.

Magnesium chloride, $MgCl_2.6H_2O$

Anhydrous salt may be prepared by passing chlorine over heated magnesium

$$Mg + Cl_2 \longrightarrow MgCl_2$$

The hydrated salt, $MgCl_2\ 6H_2O$) is obtained by dissolving, MgO or magnesium carbonate in hydrochloric acid. The solution is vaporised to obtain crystals. On a large scale it is prepared by fractional crystallisation of fused carnallite, $KClMgCl_2.6H_2O$.

Uses. It is used in cotton dressings for surgery and in dental filling pastes and sorel's cement.

Magnesium sulphate (Epsom salt) $MgSO_4\ 7H_2O$. In nature magnesium sulphate occurs as *kieserite* $MgSO_4.H_2O$ and epsom salt $MgSO_4.7H_2O$

It may be prepared by action of dilute H_2SO_4 on magnesium oxide or carbonate minerals.

$$MgO + H_2SO_4 \longrightarrow MgSO_4 + H_2O$$

$$MgCO_3 + H_2SO_4 \longrightarrow MgSO_4 + CO_2 + H_2O$$

Preparation. The crystals of $MgSO_4 + 7H_2O$ are formed when a saturated solution of kiesorite is cooled.

Uses. In medicine as a saline purgative and for fire proof textiles and wood. As a catalyst in Schoder Grillo process for manufacture of sulphuric acid.

Calcium oxide. Calcium oxide is commonly known as quicklime. Calcium oxide is manufactured by heating lime stone (calcium carbonate) to a temperature of 800° C to 1000° C in a lime klin.

$$CaCO_3 \xrightarrow{\text{heat}} CaO + CO_2 \uparrow$$

Quick lime

Properties. Calcium oxide is a white amorphous solid. It melts at a high temperature (2600°C). It is very stable and does not

decompose even on fusion.

Reaction with chlorine. It reacts with chlorine to form calcium oxychloride which is called bleaching powder

$$CaO + Cl_2 \longrightarrow CaOCl_2$$

Reaction with Ammonia Chloride. It reacts with ammonium chloride to form ammonia gas

$$CaO + 2NH_4Cl \rightarrow 2NH_3 + CaCl_2 + H_2O$$

Reaction with acid. It is basic in nature, so it reacts with acid to form salts.

Action of air. When calcium oxide is kept exposed to the atmosphere is first absorbs moisture (water) from the air to form a white powder of calcium hydroxide.

$$CaO + H_2O \text{ (From Air)} \longrightarrow Ca(OH)_2$$

$$CaO + 2HCl \longrightarrow CaCl_2 + H_2O$$

Uses. It is used in a basic lining in a furnace. For drying gases and alcohol. In the manufacture of cement and glass. In the manufacture of bleaching powder.

Calcium hydroxide. is also known as

slaked lime [Ca $(OH)_2$] and is prepared by the action of water on quicklime

$$CaO + H_2O \longrightarrow Ca(OH)_2 + 15 \text{ Kcal.}$$

Uses. In white washing, in softening hard water by precipitating bicarbonates. For making soil alkaline. As a disinfectant in public places and in medicine. **Calcium chloride ($CaCl.6H_2O$)**

Preparation. It can be prepared in laboratory by the action HCl on calcium oxide (lime) or carbonate

$$CaO + 2HCl \longrightarrow CaCl_2 + H_2O$$

On evaporating the solution calcium chloride is obtained as crystal of hexahydrate($CaCl_2.6H_2O$). Anhydrous crystals are obtained by heating hydrated crystals strongly.

Uses. It is used as a dehydrating agent. In preparing freezing mixture with ice and for making combustible articles, fire-resisting.

Calcium sulphate $CaSO_4.2H_2O$. In nature it is found as gypsum or albaster ($CaSO_4.2H_2O$).

Preparation. It can be prepared by the action of dilute sulphuric acid on lime or calcium carbonate

$$CaCO_3 + H_2SO_4 \longrightarrow CaSO_4 + H_2O + CO_2$$

Uses. It is mainly used in preparing plaster of paris.

Plaster of paris $CaSO_4.\frac{1}{2}H_2O$

This is prepared by heating gypsum to 120° – 130°C

$$CaSO_4.2H_2O(s) \xrightarrow{\text{Heat}} CaSO_4.\frac{1}{2}H_2O$$

Calcium carbide, CaC_2

(i) **Preparation.** is prepared by heating strongly a mixture of calcium oxide and powdered coke in the ratio 2.3 in an electrical furnace to a temperature over 2300K.

$$CaO + 3C \longrightarrow CaC_2 + CO$$

Uses. It is used in the preparation of acetylene gas. In the manufacture of nitrolim ($CaCN_2 + C$) fertilizers. As a reducing agent at high temperatures..

Calcium hydride, CaH_2

(i) **Preparation.** It is prepared by passing hydrogen over calcium heated to 670 K

$$Ca + H_2 \longrightarrow CaH_2$$

Uses. Under the name hydrolith it is used as a source of hydrogen (1 g of it with water yields 1070 ml of the gas at STP).

Composition of cement. The percentage composition of ordinary cement in terms of CaO, Al_2O_3 and SiO_2 is as follows:

Silica SiO_2	—	22%
Calcium oxide CaO	—	62%
Alumina Al_2O_3	—	7%
Other oxides	—	9%

Properties of Alkaline earth metals. Because of their low ionisation potentials they have a tendency to lose two electrons per atom to form cations with stable configuration. Therefore they act as good reducing agent.

Alkali metals loses one valence electron to achieve a noble gas configuration where as alkaline earth metals have to lose two

electrons. Alkaline earth metals form cations less readily than alkali metals. Hence alkaline earth metals are more electropositive than alkali metals.

BORON AND ALUMINIUM

The elements present in group IIIA of the periodic table are Boron (B), Aluminium (Al), Gallium (Ga), Indium (In) and Thalium (Tl), these are all p-block elements.

Electronic configuration

Element	*Symbol*	*At. No.*	*Electronic configuration*
Boron	B	5	[He] $2s^2,2p^1$
Aluminium	Al	13	[Ne] $3s^2,3p^1$
Gallium	Ga	31	[Ar] $3d^{10}4^24p^1$
Indium	In	49	[Kr] $4d^{10}5s^25p^1$
Thalium	Tl	81	[Xe] $4f^{14},5d^{10},6s^2,6p^1$

Some characteristics of the elements of group IIIA

Their atoms are smaller and nuclear charge larger, so they have high ionization energies. Due to this they are less electropositive (metallic) compared to IA and IIA metals.

They have valency electrons and have the general electronic configuration ns^2np^1, so they form either trivalent cations (Al^{2+}, etc.) or form three covalent bonds by means of sp^2 hybridization.

Their ionization energy decreases down the group and so metallic character increases down the group.

Boron shows anomalous behaviour for example it behaves like a non-metal, has high m.p. and b.p. and resembles silicon.

Their cations (Al^{3+} etc.) are hydrated due to small size and high charge.

Properties. It is unaffected by air at ordinary temperature but when heated in air at 975 K it burns forming boron trioxide and a little boron nitride.

$$4B + 3O_2 \longrightarrow 2B_2O_3$$

$$2B + N_2 \longrightarrow 2BN$$

Action of NaOH. It dissolves in fused NaOH forming borates

$$2B + 6OH^- \longrightarrow 2BO_{32} + 3H_2$$

Action of Acid. Amorphous boron dissolves in hot HNO_3 and H_2SO_4 to form basic acids

$$B + 3HNO_2 \longrightarrow H_3BO_2 + 3NO_2$$

$$2B + 3H_2SO_4 \longrightarrow 2H_2BO_3 + 3SO_2$$

As reducing agent. Boron is a powerful reducing agent

$$3CO_2 + 4B \longrightarrow 2B_2O_3 + 3C$$

$$3SiO_2 + 4B \longrightarrow 2B_2O_3 + 3Si$$

Uses. It is used as a deoxidizer for casting copper, is used in steel industry, for increasing the hardness of steel as a semiconductor. It is used in glass industry and used as flax.

Ores of boron.

Basic acid....H_3BO_3

Colemanite.....$Ca_2B_6O_{11}.5H_2O$

Boracite.....$2Mg_3B_8O_{15}.MgCl_2$

Borax...$Na_2B_4O_7.10H_2O$

Extraction of boron. It is prepared by the reduction of boric oxide with magnesium at high temperature.

$$B_2O_3 + 3Mg \longrightarrow 2B + 3MgO$$

The above mixture is boiled with conc. HCl, magnesium oxide dissolves out where as amorphous boron is obtained as a residue.

It is washed with water and dried

$$MgO + 2HCl \longrightarrow MgCl_2 + H_2O$$

Aluminium Bauxite: $Al_2O_3.2H_2O$

Cryolite: Na_3AlF_6

Felspar: $KAlSi_3O_8$

Mica: $KAl_3Si_3O_{10}(OH)_2$.

Extraction of Aluminium. Metallic aluminium is produced by the electrolysis of alumina dissolved in the fused cryolite Na_3AlF_6 with a little Fluorspar (CaF_2) for lowering the temperature of the melt. Cell is lined with graphite serving as cathode and a

number of graphite rods are inserted vertically as anode on passing current aluminium is set free at the cathode and deposits on the floor of the furnace while oxygen is evolved at anode.

Properties of Aluminium. Aluminium is silvery white light metal (sq.gr. = 2.7). It is a good conductor of electricity and it is highly malleable and ductile.

Pure water has no effect on Al. It decomposes boiling water. It dissolves in acids to form salts. Al reduces metallic oxide on account of its great affinity to oxygen. The heat liberated is so great as to produce molten metals.

Uses of Aluminium. It is used in the manufacture of household articles. For making alloys. Al powder as a paint pigment.

Alumino thermic process. The reduction of metallic oxides by aluminium is an exothermic process. The heat liberated is so great that the metal produced is in molten state. This process is called alumino thermic process.

Thermit process. A clay mould is built around the broken part. A crucible with a plug in the bottom is fitted in it.

Thermit mixture (a mixture of ferric oxide, aluminium and magnesium powders) is fitted in it. On the top is placed a mixture of barium peroxide (oxidising agent) and magnesium powder. It is ignited by a magnesium ribbon inserted in the ignition mixture.

$$Fe_2O_3 + 2Al \longrightarrow 2Fe + Al_2O_3 + Heat.$$

The heat so produced makes the iron near to its boiling point. The plug in the bottom is removed. Molten iron falls on the broken part and melts it.

Uses. (i) It is used in welding of iron. For the preparation of metals like chromium, whose oxides are difficult to reduce.

Boron has high m.p. and b.p. because atoms are most firmly bound to another in both solid and liquid states. Huge amount of energy is required to break these bonds. That is why it has high m.p. and b.p.

Boron is trivalent. boron has electronic configuration $1s^2\ 2s^2\ 2p^1$. For formation of

three equivalent bonds one of the 2s electron is promoted to the vacant 2p orbital on 2s and two 2p orbitals hybridize to give three equivalent sp^2 hybrid orbitals. So boron is trivalent.

Aluminium is a good reducing agent. Al is a good reducing agent because it has a great affinity for oxygen. So it can reduce a large number of oxides of metals and non metals.

$$2Al + Cr_2O_3 \longrightarrow 2Cr + Al_2O_3 + Heat$$

$$2Al + B_2O_3 \longrightarrow 2B + Al_2O_3$$

Aluminium Chloride $AlCl_2$

Preparation. (I) By heating aluminium in dry chlorine

$$2Al + 3Cl_2 \longrightarrow 2AlCl_3$$

(II) By passing Cl_2 gas over heated mixture of Al_2O_3 and carbon

$$Al_2O_3 + 3Cl_2 + 3C \longrightarrow 2AlCl_3 + 3CO$$

Properties. It is white crystalline solid and sublime at 456K. It exists in dimeric form. It is soluble in organic solvents. It gets

hydrolysed by water giving acidic solution.

$$AlCl_3 + 3HOH \longrightarrow Al(OH)_3 + 3HCl$$

It absorbs ammonia giving hexa-ammoniate, $AlCl_3, 6NH_3$.

Alumina Al_2O_3 Preparation. By igniting aluminium hydroxide or nitrate.

$$2Al(OH)_3 \longrightarrow Al_2O_3 + 3H_2O$$

(ii) On commercial scale it is prepared from bauxite.

Properties. Al_2O_3 is white amorphous powder, insoluble in water. It is an amphoteric oxide i.e. dissolves in both acids and alkalies.

$$Al_2O_3 + 3H_2SO_4 \longrightarrow Al_2(SO_4)_3 + 2H_2O$$

$$Al_2O_3 + 2NaOH \longrightarrow 2NaAlO_2 + H_2O$$

Uses (i) Corundum for furnace lining.

(ii) For extraction of aluminium metal.

(iii) Crystalline alumina as an abrasive.

Aluminium hydroxide $Al(OH)_3$

Preparation. By adding NH_4OH to a soluble salt of

$$AlCl_3 + 3NH_4OH \longrightarrow Al(OH)_2 + 3NH_4Cl$$

Properties. It is a white amorphos powder insoluble in water. It is amphoteric in nature and reacts with both acids and alkalies.

$$Al(OH)_3 + 3HNO_3 \longrightarrow Al(ON_3)_2 + 3H_2O$$

$$Al(OH)_3 + NaOH \longrightarrow NaAlO_2 + 2H_2O$$

It loses water on heating.

$$2Al(OH)_3 \xrightarrow{Heat} Al_2O_3 + 3H_2O.$$

Uses. This used as a mordant for fixing certain dyes on cotton cloth. In the preparation of other aluminium salts.

Boric acid from borax. A hot concentrated solution of borox is treated with a calculated quantity conc. H_2SO_4 or HCl. On cooling crystals of boric acid separates out.

$$Na_2B_4O_7(aq) + 2HCl(aq) + 5H_2O(l) \longrightarrow 2NaCl + 4H_3BO_3$$

Properties. It is a white crystailine substance, soft and soapy touch. It is a weak mono basic acid and in solution gives only a wine red colour with litmus. It does not affect methyl orange.

$$H_3BO_3\ H_3O^+ + H_2BO_3^-.$$

Action of heat. When orthoboric acid is heated it gives metaboric acid at 370K. and finally boron an hydride at red heat.

$$2H_3BO_3 \xrightarrow[370K]{-2H_2O} 2HBO_2 \xrightarrow{-H_2O} B_2O_3$$

Uses. It is used in glass industry and as antiseptic. It is also used as a preservative.

Alums. is the name given to the double salt of potassium and aluminium sulphate $(K_2SO_4Al_2(SO_4)_324H_2O$ but the general formula now a days is $M_2SO_4M_2(SO_4)24H_2O$. Where M = H^+, Na^+, Rb^+, NH_{4+}, $^{Ag+}$ $^{etc.}M^{'}$ = $Al3+'$ $^{Fe3+'}$ $^{Cr}3+$ $^{etc.}$

Common example., Potash alum $K_2SO_4Al_2(SO_4)_32H_2O$

Sodium alum $NaAl(SO_4)_212H_2O$

Ammonium alum $(NH_4)Al(SO_4)_212H_2O$

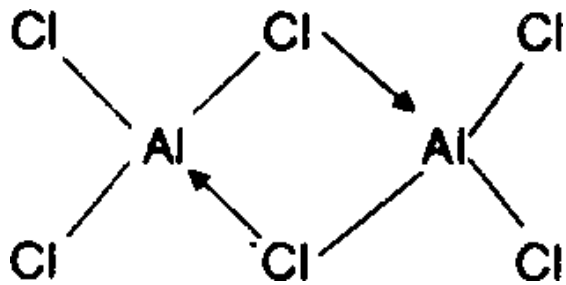
Preparation of potash alum. It is prepared by mixing hot solutions of equimolecular quantities of potassium sulphate

(174gm) and aluminium sulphate crystals (666gms.) The mixed solution is cooled to get crystals of alum.

Properties. It is less soluble in water but the solubility increases with increase of temperature. It is insoluble in alcohol. It melts at 396K and at 473K loses all its water of crystallisation and turns to a porous mass. Anhydrous alum is known as "burnt alum".

Uses. It is used as mordant. In tanning halides. For coagulating muddy water. In calico printing. In fire extinguishers. For sizing papers.

Structure of anhydrous aluminium chloride. The vapour density of aluminium chloride at low temperature indicates its formula to be Al_2Cl_6(dimer). Its structure may be



In structure, each aluminium atom achieves an octet by accepting a lone pair of electrons from the chlorine atom of another aluminium chloride molecule. This has been confirmed by X-ray studies.

Alloys of Aluminium

Alloy	*Composition*	*Properties*	*Uses*
Aluminium bronze	Cu= 94.88% Al=5.12%	golden colour corrosion resistant.	For making utensils, jewellery, coins, etc.
Duralumin	Al=95% Cu=4% Mg=0.5% Mn=0.5%	light, hard, corrosion resistant and highly ductile.	In making aircrafts and seacrafts.

Mag-nali m	Mg=5 to 15% Al=95 to 85%	Hard and tough.	In making parts of machine and cheap balances.
Nicke-loy	Ni=1% Cu=4% Al=95%	Very light and tough.	In making aircraft.
Alnico	Fe=50% Ni=20% Al=20% Cu=10%	Highly magnetic	In making powerful and perma-nent magnets.

THE CARBON FAMILY

Element of group IVA. Group IVA of the periodic table consists of carbon (C), silicon (Si), Germanium (Ge), Tin(Sn) and lead (Pb).

Electronic configuration of group IVA

Element	*Symbol*	*At No.*	*Electronic configuration*
Carbon	C	6	$[He]2s^2 2p^2$
Lead	Pb	82	$[Xe]5d^{14}4d^{10}6s^2 6p^2$
Silicon	Si	14	$[Ne]3s^2 3p^2$
Germanium	Ge	32	$[Ar]3d^{10}4s^2 4p^2$
Tin	Sn	50	$[Kr]4d^{10}5^{82}5p^2$

General Characteristics

Electronegativity. The electronegativity decreases gradually from carbon to lead. This is due to filling of d-orbitals and later f-orbitals. Thus there is a gradual transition from the electronegative carbon to the electropositive lead with rise in atomic number.

Metallic character. The metallic character increases down the group. Carbon and silicon are non-metals, germanium is a metalloid while tin and lead are metals.

Hydrides. All these elements form covalent hydrides. The number and the ease with which hydrides are formed decreases from carbon to lead.

Ionization energy. Their ionization energies are high and decreases from carbon to lead.

Oxides. They all form dioxides of the general formula XO_2. Carbon dioxide and silica are acidic. The acidity falls with the rise of atomic number.

Halides. All these elements give tetrahalides which are tetrahadral and covalent. Tetrachloride are usually forming liquids at ordinary temperature.

Tetra-covalency of elements of group IVA carbon. Its atomic number is 6 and electronic configuration is $1s^2$, $2s^2$, $2px^1$, $2py^1$. As such carbon must be divalent in nature, but in its compounds carbon is tetravalent in nature. To achieve this on electron gets promoted from 2s filled orbital to 2p empty orbital. Therefore the excited state configuration is $1s^2$, $2s^1$, $2px^1$, spy^1, $2pz^1$.

As the number of unpaired electrons in the valence shell of carbon is four, it is tetravalent in nature.

Solid CO_2 is known as ice. Solid CO_2 looks like ice and it is called dry ice because it does not wet a piece of cloth as it sublimes without melting whereas ordinary ice wets a piece of cloth on melting.

Carborundum. It is silicon carbine Sic. It is extremely hard and used for polishing surfaces.

Zeolites. Zeolites are naturally occurring aluminium silicates. In zeolites, some of the silicon ions Si^{4-} are replaced by Al^{3+} ions. In order to maintain electrical neutrality, some other ions such as Na^{+} and Ca^{2+} are also present.

Cantenation. Carbon has a property of joining with one another in large numbers forming the long chains and rings. This action is known as cantenation. The tendency of an element to form chains is related to the strength of element, element bond which is maximum in case of carbon. The strength of

element-element decreases in group IV A with increase in atomic number so the tendency to form long chains also decreases.

TIN

Ores of Tin. Cassiterite or Tin stone... SnO_2.

Extraction of Tin. The ore is produced and concentrated by washing in a current of water. The concentrated ore is then roasted and reduced by heating with powdered coke.

$$SnO_2 + 2C \longrightarrow Sn + 2CO.$$

Uses of Tin. It is used in the preparation of alloys like solder (Sn, Pb). For a tin plating of iron sheets. For tin plating of copper and brass cooking vessels.

Alloys of Tin

Name of Alloy	*Composition*	*Uses*
Solder	Sn 67% Pb 33%	Soldering

Bronze	Sn 15% Pb 85%	Vessels and statues
Rose metal	Sn 28% Pb 22% Bi 50%	For making electric fuses
Type metals	Sn 3% Pb 12% Cu 6%	Type in printing
White metal	Sn 82% Sb 12% Cu 6%	Cable wires
Bell metal	Cu 80% Sn 20%	For making bells

LEAD (Pb)

Occurrence. Lead occurs principally as Galena, PbS; other ores are Cerusite $PbCO_3$ anglesite, $PbSO_4$ and matlokite $PbCl_2.PbO$

Extraction. The ore galena PbS, is powdered and concentrated by froth floatation process. The concentrated ore is roasted in air to its oxide

$$2PbS + 3O_2 \longrightarrow 2PbO + 2SO_2\uparrow$$

The oxide PbO is then reduced to the metal with carbon

$$PbO + C \longrightarrow Pb + CO_2\uparrow$$
$$2PbO + PbS \longrightarrow 3Pb + SO_2\uparrow$$

Lead obtained in this way contain a number of impurities. It is refined chemically or electrolytically.

In electrolytic method, the anode consists of impure lead, the cathode of pure lead and electrolyte is lead silico-fluoride $PbSiF_6$.

Properties. Lead is a soft bluish white metal with a bright lusture on a freshly cut surface, but quickly tranishing in air to a dull grey blue. It is melleable and ductile. Lead is unaffected by dry air but in presence of moisture it tranishes due to formation of a thin film of the hydroxide. It is attacked by all acids

$$Pb + 2HCl \longrightarrow PbCl_2 + H_2$$
$$Pb + 2H_2SO_4 \longrightarrow PbSO_4 + 2H_2O + SO_2$$

Uses. It is used as plates in storage batteries. Alloys; type metal solder etc. In sulphuric acid industry (lead chamber). Its compounds as pigments for making pipes.

White lead, $Pb(OH)_2$, $2PbCO_2$. It is prepared by treating finely divided lead with

dil. acetic acid, moist air and carbon dioxide gas in rotating cylinder

$$2Pb + 2CH_2COOH + O_2 \longrightarrow Pb(OH)_2Pb(CH_3COO)_2$$

$$3Pb(OH)_2.Pb(CH_3COO)_2 + 4CO_2 + 2H_2O \longrightarrow 2Pb(OH)_2.2PbCO_3 + 6CH_3COOH$$

white lead

White lead is used as a white pigment.

Chrome yellow ($PbCrO_4$). It is prepared by adding potassium chromate solution to a soluble lead salt solution

$$Pb(NO_3)_2 + K_2CrO_4 \longrightarrow PbCrO_4 + 2KNO_3$$

Lead chromate is extremely insoluble in water and is used as a yellow pigment.

Red lead (Pb_3O_4). It is prepared by heating lead oxide in air to about 700K.

$$PbO + O_2 \rightarrow 2P_3O_4$$

It is used as red pigment especially for the protection of iron from rusting. It is insoluble in water, but dissolves partially in nitric acid. It is brilliant red in colour and can be mixed in linseed oil.

Lead tetraethyl, $Pb(C_2H_4)_4$. It is prepared by treating an alloy of sodium and lead with ethyl bromide. C_2H_3Br

$$4C_2H_3Br + NaPb \longrightarrow Pb(C_2H_5)_4 + 4NaBr + 3Pb$$

It is colourless liquid soluble in petrol. It is used to improve the quality of petrol as it is an effective anti knock agent.

THE NITROGEN FAMILY

Elements included in the group VA of the period table. Five elements Nitrogen (N), Phosphorous (P) Asenic (As), Antimony (Sb), Bismuth (Bi) occupy the group VA of the periodic table because all these have 5 valence electrons.

Element	*Atomic number*	*Electronic configuration*
Nitrogen	7	[He] $2s^2\ 2p^3$
Phos-phorous	15	[Ne] $3s^2\ 3p^3$

Arsenic	33	$[Ar]\ 3d^{10}\ 4s^2\ 4p^3$
Antimony	51	$[Kr]\ 4d^{10}\ 5s^2\ {}^5P_3$
Bismuth	83	$[Xe]\ 4f^{14}\ 5d^{10}\ 6_{s2}{}^6p_3$

General characteristics

Allotropy. All elements except Bismuth show allotropy.

Physical state. The first element nitrogen is a gas. The phosphorous is a soft waxy solid. Arsenic is a hard solid whereas arsenic and Bismuth are hard solids with metallic lusture.

Atomic radius. Atomic radius increases with increases in atomic number.

Melting and boiling points. The m.p. and b.p. of the elements of this group do not follow a particular order. There is an increase of m.p. from N to As. The b.p. increases regularly on moving down the group from N to Bi.

Metallic character. Nitrogen and phosphorous are non-metals. Arsenic and An-

timony are metalloids and Bismuth is a metal.

Basic character. The basic character of hydrides decreases with rise in atomic number.

Sulphides. Except nitrogen all the elements of this group form sulphides.

Ionization energy. The ionization energy of nitrogen is very high due to its small atomic radius. This value decreases down the group.

Electro-negativity. The element of group VA have higher values of electro-negativity. This value decrease gradually down the group.

Hydrides. All elements of this group from hydrides of the type RH_3. All these are covalent and pyramidal in shape.

Oxides. All the elements of group VA from oxides of the general formula R_2O_3 and R_2O_5 called tri and pentaoxides. N.P., Sb and Bi also forms dioxides of the type RO_2.

Anamalous behaviour. N_2 shows the anamalous behaviour because (i) Its smal-

lest size (0.75A) (ii) Its highest electronegativity (3.0). (iii) Its highest ionization energy (1403 kj mol^{-1}). (iv) absence of d orbital ($1s^2$, $2s^2$ $2p^3$).

Properties in which N_2 differs from other member of group.

(i) Nitrogen is a gas while other members are solid.

(ii) Due to absence of *d* orbitals its maximum coordination number is 4 while it is 6 for others.

(iii) Halides of N_2 are unstable (except NF_6) other elements form stable halides.

(iv) It can form hydrogen bonds while others can not.

(v) It shows more oxidation states (–3,–2,–10,+1,+2, +3, +4, +5) than any other element of this group.

(vi) It is relatively inert due to strong N≡N bonding.

Oxidation states shown by group VA elements. The outer ns^2np^3 electronic con-

figuration of group VA elements suggests three possible oxidation states −3, +3 and +5. (i) -3 by gaining 3 electrons to attain the noble gas configuration e.g., Ca_3I_2, $Na_2As.Mg_3N_2$ etc. (ii) +3 by loosing three electrons or by sharing three np^3 electrons with more electronegative elements *e.g.*, BiF_3, N_2O_3 etc. (iii) +5, by sharing 5 valence electrons with more electronegative element *e.g.*, N_2O_5 (iv) Nitrogen also shows -1, -2, +1, +2, and +4 oxidation states in addition −3, +3 and +5, *e.g.*, NH_4OH (-1). N_2H_4 (-2) N_2O (+1), NO (+2) and N_2O_4 (+4).

Nitrogen does not form pentahalide. The atomic number of nitrogen is 7 and at electronic configuration is $1s^2$, $2s^2$, $2px^1$, $2py^1$ $2pz^1$. As there is no vacant orbitals in the valence shell of the atom, nitrogen cannot exhibit valancy more than three. Therefore nitrogen does not form Pentahalide.

Ammonia. On large scale, ammonia is prepared by direct combination of nitrogen and hydrogen

$$N_2 + 3H_2 \rightleftharpoons 2NH_3 + 93.6kJ\ mol^{-1}$$

The reaction is exothermic according to Le Chatelier principle.

Low temperature will shift the equilibrium towards right.

High pressure will favour the formation of ammonia.

Process. The nitrogen and hydrogen are mixed in the volume ratio of 1:3 and are pressed to a pressure of 200-800 atmospheres. The compressed gas mixture is passed over finally divided iron molybdenum

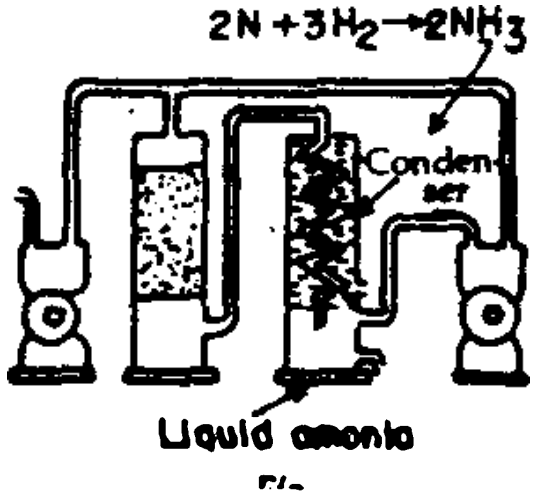


Fig.

catalyst heated to 700-750 K. The gas coming out from this chamber may contain 15 to 40%. Ammonia is converted in liquid form by cooling. The unused gases are again sent back to the plant with the help of a recirculating pump.

Properties It is a colourless gas with a strong pungent odour and highly soluble in water

$$NH_3 + H_2O \; NH_4^+ + OH^-$$

Oxidation. When ammonia is burnt in air or passed over heated copper oxide it oxidised to nitrogen

$$3CuO + 2NH_3 \longrightarrow 3Cu + N_2 + 3H_2O$$

Amide formation. With sodium or potassium metal it gives an amide

$$2NH_3 + 2Na \longrightarrow 2NaNH_2 + H_2(g)$$
(Sedamide)

Basic character. Ammonia has a strong tendency to donate its lone pair of electrons to other molecules. It is therefore a strong lewis base. Because of the lone pair of electrons, NH_3 reacts with metal cations

yieldings complexes.

$$Ag^{+} + 2\,NH_3 = [Ag(NH_3)_2]^{+}$$

$$Cu^{2+} + 4\,NH_3 = [Cu(NH_3)_4]^{2+}$$

Uses of ammonia. (i) As a refrigerating agent. Used for the preparation of urea a very important fertilizer. Used as a laboratory reagent.

Phosphorus (i) Apatite... $Ca_3(PO_4)_2$

(ii) Fluorapatite... $3Ca_3(PO_4)_2CaF_2$

(iii) Chloraphite... $3Ca_3(PO_4)\,CaCl_2$

Extraction of phosphorus. Phosphorus is obtained by directly heating mineral phosphorites with silica and coke.

$$Ca_3(PO_4)_2 + 3SiO_2 \longrightarrow 3CaSiO_3 + P_2O_3$$

$$2P_2O_3 + 10C \longrightarrow 10CO\uparrow + P_4$$

The above reaction occurs at 1500 K. The electric furnace used is shown. The charge is fed continuously through a hopper. Molten calcium silicate is removed as a slage from the lower opening. The vapour of phosphorous is led under water for condensation as white phosphrous.

Uses. It is used in match industry. It is used for incendiary bomb and smoke screen. In the manufacture of phosphor bronze an alloy.

Preparation of orthophosphoric acid. (1) By dissolving phosphorus pentaoxide in warm water

$$P_4O_{10} + 6H_2O \longrightarrow 4H_3PO_4$$

(2) By oxidising red phosphorus by heating with 50% HNO_3, oxides of nitrogen are evolved

$$3P_4 + 20HNO_3 + 8H_2O \longrightarrow 12H_3PO_4 + 20NO$$

$$P_4 + 20HNO_3 \rightarrow 4H_3PO_4 + 20NO_2 + 4H_2O.$$

Preparation of phosphorus trioxide P_4O_6. By burning phosphorous in a limited supply of air.

$$P_4 + 3O_2 \longrightarrow P_4O_6$$

Properties (1) It is a white solid which dissolves in water to give phosphorus acid

$$P_4O_6 + 3H_2O \longrightarrow 4H_3PO_3$$

(2) With excess of air it forms the pentaoxide

$$P_4O_6 + 2O_2 \rightarrow P_4O_{10}$$

Preparation of phosphorus pentaoxide P_4O_{10}. By burning phosphorus in excess of air

$$P_4 + 5O_2 \longrightarrow P_4O_{10}$$

Properties. (1) It is an acidic oxide and dissolves in excess of water to form ultimately orthophosphoric acid

$$P_4O_{10} + 3H_2O \rightarrow 4H_3PO_3$$

(2) It is a strong dehydrating agent e.g. it removes water molecules from concentrated nitric acid and conc. H_2SO_4.

$$P_4O_{10} + 2H_2SO_4 \longrightarrow 2SO_3 + 4HPO_3$$

$$P_4O_{10} + 4HNO_3 \longrightarrow 2N_2O_5 + 4HPO_3$$

FUELS AS AN ENERGY

Fuels. Materials used for producing heat are known as fuels. The commonly used fuels are kerosene, diesel, coke, wood, charcoal, petrol, gas etc. Wood, agriculture waste and cowdung supply nearly 80% of the energy used in villages of India.

Biomass. The material contained in the bodies of plants and animals is called

biomass. When organisms die, their biomass can be used as fuel. (Wood and cow dung are the examples)

Bagasse. The remains of sugarcane from which sugar juice has been extracted is called bagasse. It is used as a fuel for heating industrial boilers.

Charcoal. Half burnt wood is known as charcoal. Charcoal is a better fuel than wood as it possesses higher calorific value.

Good Fuel. A good fuel must have the following properties.

It should possess high calorific value. It should possess low ash content.

It should possess minimum amount of volatile materials. It should be cheap and readily available.

It should not evolve harmful products.

Biogas. is a mixture of gases like methane (65%). carbon dioxide, hydrogen and hydrogen sulphide.

Coal. It can be assumed as compressed form of charcoal present under earth's crust.

Thousands of years ago, due to effects of earth quakes and volcanos, the trees other plants were buried. Due to continuous effect of heat and pressure, the charcoal is converted into coal.

The common varieties of coal are (i) Lignite (ii) Anthracite and (iii) Bituminous coal.

Lignite. is a variety of coal which contains about 38% carbon, 19% volatile matter and 43% moisture.

Anthracite. is a variety of coal containing about 96% carbon. 1% volatile matter and 3% moisture.

Bituminous Coal. is a variety of coal with 75% carbon, 23% volatile matter and 2% moisture. Its calorific value is high.

Calorific Value of a Fuel. It is the amount of heat produced by burning one gram of fuel.

Calorific value of wood	– 17.kj/gm
Calorific value of kerosene	– 47.8 kj/gm
Calorific value of LPG	– 55 kj/gm
Calorific value of charcoal	– 33 kj/gm.

Coal Gas. A mixture of different

hydrocarbons used as fuel is known as coal gas which contains nearly 50% hydrogen, 35% methane, 8% carbon monoxide along with small quantities of benzene and ethylene.

Fossil Fuels. Fossils are formed by burial of plants and animals sedimentary rocks over millions of years. The cover of sediments delays their oxidation, while their weight squeezes out water and other volatile materials (Coal petroleum and natural gas are fossil fuels.)

Petroleum. It is a dark coloured liquid, mainly consisting of hydrocarbons. It is formed from micro-organisms living in the sea.

The process of obtaining various products in the pure form is known as refining. Refining of petroleum is based on the fact that its different products have different boiling points. They can thus be separated by fractional distillation.

Liquified Petroleum Gas (L.P.G.) Consists of hydrocarbons like propane and

butane. It is an ideal cooking gas having a calorific value of 55 kj/g. L.P.G. is obtained by fractional distillation of petroleum.

Propellants. Fuels used for propelling are known as propellants. These are special fuels that are highly compact, and burn rapidly and completely. Fuels used in rockets are known as rocket propellants

Ignition Temperature. It is the temperature at which a substance catches fire.

Carbonisation. is the process of decomposition of wood into coal under high pressure in the absence of air. But it is a very slow process.

Pesticides. Rates, Crochroches and other many insects are enemies of plants. Chemicals used to kill pests etc. are known as pesticides. The commonly used pesticides are zinc phosphide, malathion and D.D.T.; B.H.C.

Primary and Secondary Fuels. Fuels found in nature are known as primary fuels. Wood, Coal, Petroleum and natural gas are primary fuels. Secondary fuels are prepared

from primary fuels. Fuels like coke, kerosene oil, petrol, diesel, coal gas etc. are secondary fuels.

Respiration. It is a catabolic reaction in which cell constituents, like sugar, glucose etc. are converted into water and carbon dioxide with the release of energy.

Photosynthesis. It is an anabolic reaction in which CO_2 and water are absorbed to form glucose with the release of oxygen. This reaction occurs in green plants in the presence of sunlight and chlorophyl present in the plants.

Difference between Photosynthesis and Respiration

Photosynthesis	*Respiration*
Energy is stored in this process.	Energy is released in this process.
CO_2 is absorbed and O_2 is released in this process.	O_2 is absorbed and CO_2 is released in this process

Process takes place during sunlight only.	It takes place during day and night.
Increase in weight takes place during the process.	Decrease in weight takes place during the process.
It takes place in green cells.	It takes place in all types of cells.

Combustion. is a chemical reaction of burning that releases heat and light.

Difference between respiration and combustion

Respiration	*Combustion*
The reaction takes place inside the living cells.	It occurs in dead and non-living dry cells.
It is a complex biochemical process that is controlled by several enzymes.	It is a direct chemical reaction.

Quantity of heat produced is less.	Quantity of heat produced in more.
No light is produced.	Light is produced.
It is a slow process.	It is a rapid process

Calorific values of some common fuels

Fuel	*kilo joules/gm*	*Calorific values kWh/kg*
Wood	17	5.5-6.8
Dung cake	6-8	2.0-2.6
Liquid fuels		
Kerosene	48	15.5
Solid fuels	33-36	10.7-11.3
Charcoal Coal	25-33	10.7
Ethanol	30	9.6
Fuel oil	44-46	14-15

Gaseous fuels		
hydrogen	150	48.5
Butane(LPG)	55	16-16.5
Biogas	35-40	11.3-20.6
Methane	55	17.5-18.0

Liquid and Solid fuels

Calorific value of liquid fuels is high.

Dust and ash content of liquid fuels is zero.

Liquid fuels can be fired easily and can be stopped easily by switching off the supply of fuel.

They can be transported easily through pipes.

They can be stored easily and indefinitely.

The quantity of liquid fuels required for burning can be controlled easily and require lesser space for combustion.

SOME USEFUL COMPOUNDS

Bleaching Powder. Bleaching powder can be obtained by passing chlorine gas over dry slaked lime. It is a yellowish-white powder which gives strong smell of Cl_2 and is soluble in cold water.

$$Ca(OH)_2\,(s) + Cl_2\,(g) \rightarrow CaOCl_2\,(s) + H_2O\,(l)$$

Calcium oxychloride
(Bleaching powder)

Now a days bleaching powder is prepared by Bachmann's plant as shown in fig.

Dry slaked lime is put into the hoper with the help of compressed air. From the hoper, slaked lime slowly drops into the chlorinated tower which falls on the shelves. As the rake

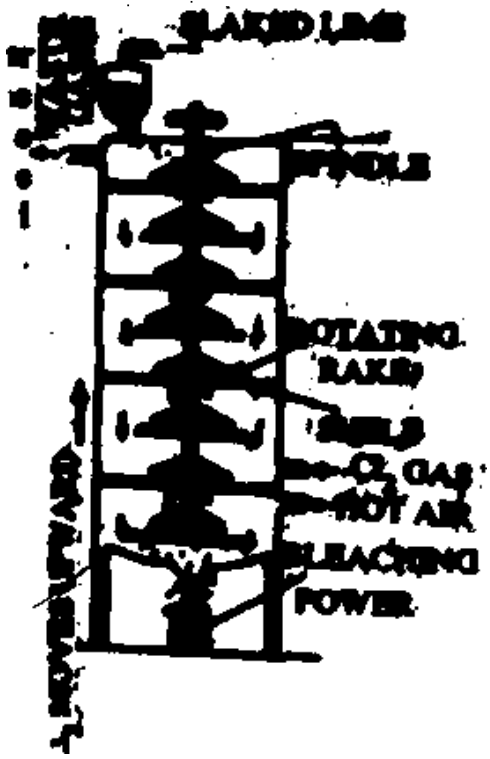


Fig.

rotates, the slaked lime moves downwards in the tower. Then chlorine gas and hot air being passed in from near the bottom of the tower. As slaked lime moves down, it faces the upcoming current of chlorine gas. The slaked lime reacts with chlorine to form bleaching powder which collects in the vessel placed at the bottom of the tower.

Properties

Reaction. When bleaching powder is treated with small amount of dilute H_2SO_4 then it produces hypochlorous acid.

$$2\,CaOCl_2 + H_2SO_4 \rightarrow CaCl_2 + CaSO_4 + 2HClO$$

Hypochlorous acid

This hypochlorous acid decomposes further to give hydrochloric acid and nascent oxygen.

$HClO \rightarrow HCl + [O]$ Nascent oxygen

This nascent oxygen is a good agent to bleach the coloured matter.

Bleaching powder reacts with carbon dioxide to produce calcium carbonate and chlorine gas.

$$CaOCl_2 + CO_2 \rightarrow CaCO_3 + Cl_2 \uparrow$$

It is used for bleaching cloth etc.

It is also used in making wool unshrinkable.

It is used in the preparation of chloroform and is used as a disinfectant and germicide for sterilization of drinking water.

Calcium Hydroxide

Calcium hydroxide is a white powder which is slightly soluble in water. A clear solution of calcium hydroxide in water is called lime water. A milky suspension of calcium hydroxide in water is called milk of lime. This is commonly known as slaked lime. It can be obtained by adding water to calcium oxide (or quick lime).

$$CaO + H_2O \rightarrow Ca(OH)_2 + \text{heat}$$

Properties.

Reaction. Slaked lime reacts with chlorine to form bleaching powder. i.e.

$$Ca(OH)_2 + Cl_2 \rightarrow CaOCl_2 + H_2O$$

Effect of heat. When Calcium hydroxide is heated strongly, water is eliminated and calcium oxide is formed

$$Ca(OH)_2 \xrightarrow{\text{Heat}} CaO + H_2O \uparrow$$

Reaction. The lime water turns milky, when carbon dioxide gas is passed through lime-water. It forms a white precipitate of calcium carbonate.

$$Ca(OH)_2\,(aq) + CO_2\,(g) \rightarrow CaCO_3\,(s) + H_2O\,(l)$$

Uses. It is used for softening temporary hard water.

It is used in the preparation of caustic soda, bleaching powder, ammonia.

Also used by farmers to reduce acidity of soil.

Calcium Oxide CaO

It is commonly known as quicklime. Calcium oxide is manufactured by heating lime stone (calcium carbonate) to a temperature of 800° C— 1000° C in a limekiln.

$$CaCO_3 \xrightarrow{\text{Heat}} CaO + CO_2\uparrow$$

Quick lime

Lime-Klin is like a furnace. When limestone is added from the top and is heated by burning coal in fire box present in the sides of the klin. Carbon dioxide produced is made to escape from the opening near the top then quick lime is collected from the bottom of the klin.

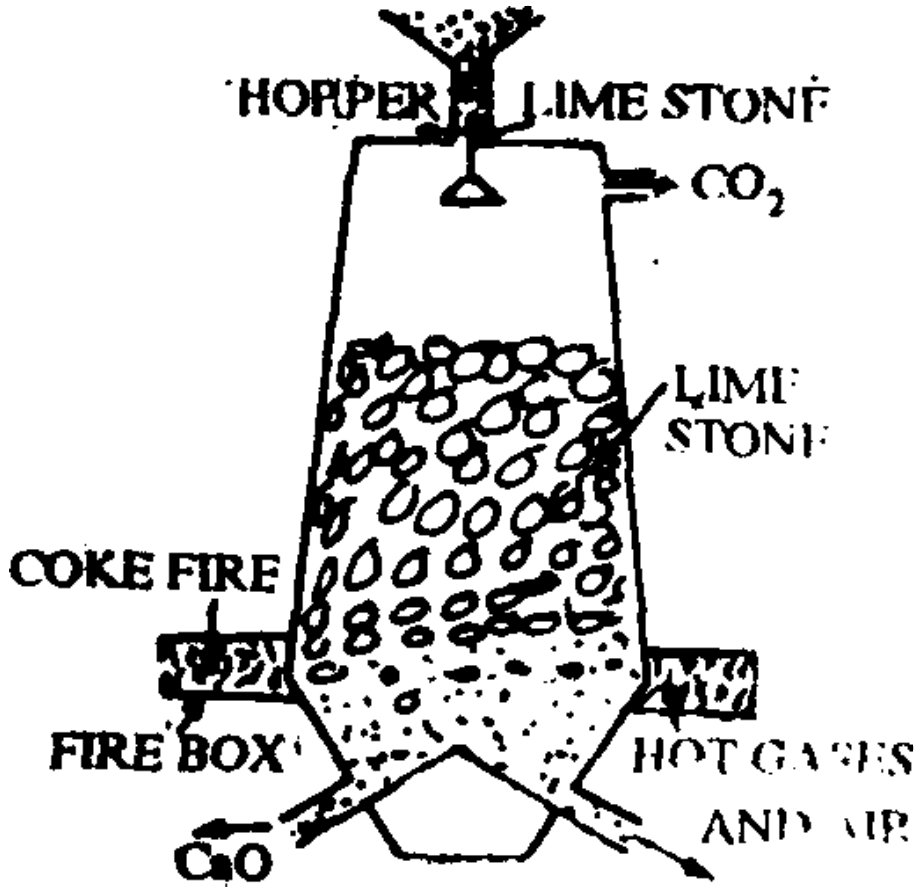


Fig.

Properties of calcium oxide.

Calcium oxide is a white amorphous solid.

It melts at a high temperature (2600° C. It is a very stable and does not decompose even on fusion.

Action of air. When calcium oxide is exposed to the atmosphere then it first ab-

sorbs moisture from the air to form a white powder of calcium hydroxide, i.e.

$$CaO + H_2O \rightarrow Ca(OH)_2$$

(From air)

Reaction. It reacts with chlorine to form calcium oxychloride which is called bleaching powder.

$$CaO + Cl_2 \rightarrow CaOCl_2$$

With Ammonia chloride. It quickly reacts with ammonium chloride to form ammonia gas.

$$CaO + 2NH_4Cl \rightarrow 2NH_3 + CaCl_2 + H_2O$$

With acid. It reacts with acid to form salts.

$$CaO + 2HCl \rightarrow CaCl_2 + H_2O$$

Uses. It is used as a basic lining in a furnace.

It is used for drying gases and alcohol and in the manufacture of cement and glass.

It is also used to manufacture of bleaching powder.

Sodium Carbonate Na_2CO_3

Sodium carbonate can be manufactured

on large scale by solvay ammonia process as shown below :-

(1) When carbon dioxide is passed through a concentrated solution of (brine) sodium chloride (NaCl) saturated with ammonia then sodium bicarbonate ($NaHCO_3$) gets precipi-tated due its low solubility in water.

$$NH_3\,(g) + H_2O\,(l) + CO_2\,(g) \rightarrow NH_4\,HCO_3\,(aq)$$

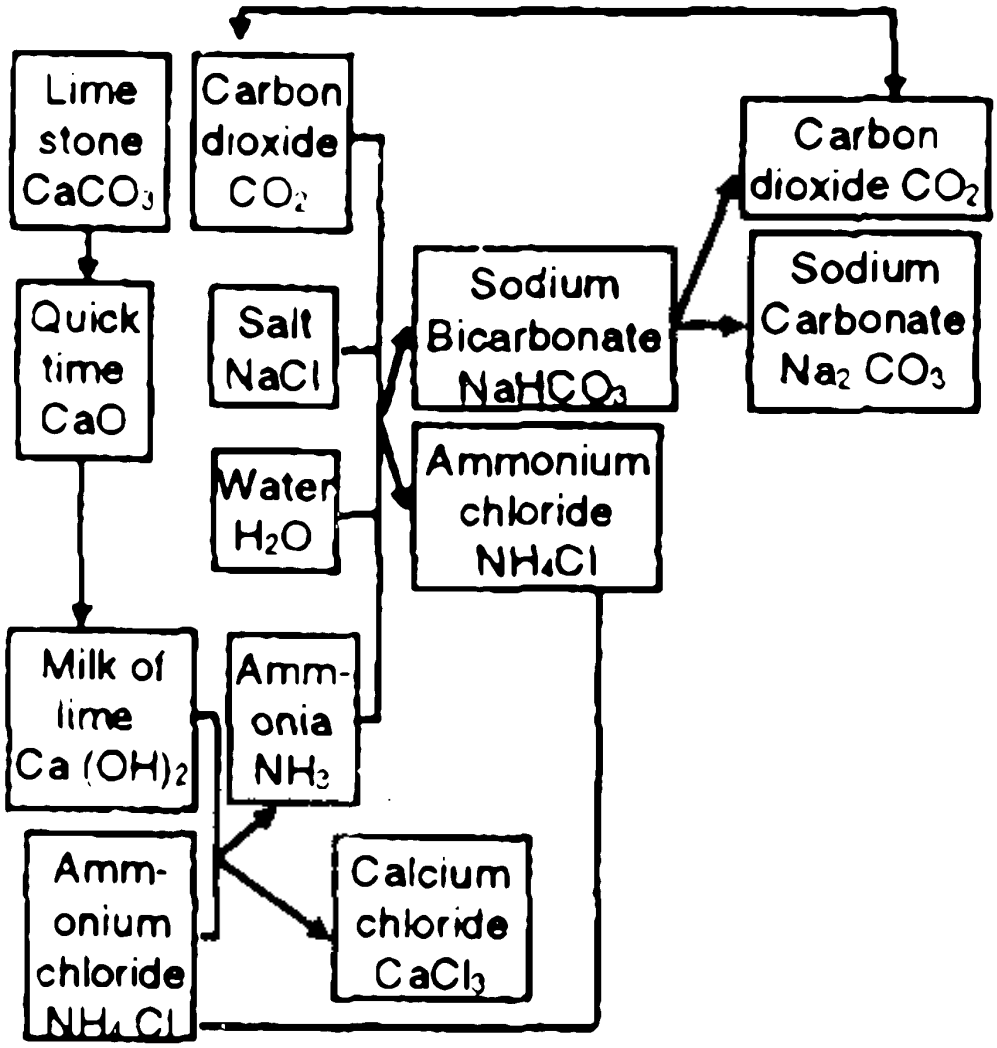
(Ammonium bicarbonate)

$$NH_4\,HCO_3\,(aq) + NaCl\,(aq) \rightarrow NH_4Cl\,(aq) + NaHCO_3(s)$$

(2) Sodium bicarbonate is obtained as a white crystalline solid by filteration. Then it is well washed so as to free from ammonium compound.

(3) This separated sodium bicarbonate is heated to convert it into sodium carbonate.

$$2\,Na\,HCO_3\,(s) \xrightarrow{\text{heat}} Na_2\,CO_3\,(s) + H_2O\,(l) + CO_2\,(g)$$



Ammonium chloride and carbon dioxide are used again and again. Hence the manufacture of sodium carbonate involves only sodium chloride as the cheap raw material.

Properties. When anahydrous it melts at

862° C. This dissolve in water the evolution of heat. Its aqueous solution is alkaline due to hydrolysis and its solutions turn red litmus blue.

$$Na_2CO_3\ (s) + H_2O\ (l) \rightarrow 2NaOH\ (aq) + CO_2(g)$$

When its hot concentrated solution gives. $Na_3CO_3\ 10H_2O$ (decahydrate). If this variety is exposed to air, it efforesces and finally changes into monohydrate $Na_2\ CO_3\ H_2O$

On strong heating, it changes into anhydrous.

This reacts with mineral acids to give carbon dioxide gas.

$$Na_2CO_3(s) + 2HCl\ (aq) \rightarrow 2\ NaCl(s) + CO_2(g) + H_2O(l)$$

It's uses are as follows—

(1) It is used in the manufacture of glass, soap powder.

(2) Used as a washing soda and in the softening of water.

(3) It is used as a base in acid base titration.

Copper sulphate (Blue vitriol)

$CuSO_4\ 5H_2O$ is blue vitriol. It is manufactured by dissolving copper scraps in hot dilute sulphuric acid in presence of air.

$$2Cu(s) + 2H_2SO_4(aq) + O_2(g) \rightarrow 2CuSO_4(s) + 2H_2O.$$

But at a controlled temperature generally it is prepared by roasting copper pyrites in air.

Properties. The crystalline salt is blue in colour and it contains 5 molecules of water of crystallization but on exposure to air pale blue salt is obtained. $CuSO_4\ 3H_2O$.

At 100° C it is converted into monohydrate $CuSO_4.\ H_2O$ which is bluish white in colour. The anhydrous salt is white when treated, with water it changes to blue. This process shows that dehydration of copper sulphate is a reversible process. This is soluble in water and forms complex ammonia solution.

Uses. It is used in agriculture as fungicide and germicide.

It is used for electroplating and for dyeing and for the preparation of many other salts.

Plaster of Paris $CaSO_4 . \frac{1}{2} H_2O$

This is prepared by heating gypsum to 120° — 130° C

$$CaSO_4 . 2H_2O(s) \xrightarrow{\text{Heat}} CaSO_4 . \frac{1}{2} H_2O$$

When mixed with water it form a solid plastic mass and if heat is given out during this process then it forms a hard porous mass within 10—15 minutes. This is due to two steps.

Firstly water is absorbed to form orthorhombic dihydrate and changes to monoclinic where the plaster hardens and the property of setting takes place.

$$CaSO_4 + 1/2\ H_2O \xrightarrow{H_2O} CaSO_4$$

$$2H_2O \xrightarrow{H_2O} CaSO_4\ 2H_2O$$

Uses. It is used in making black board, chalks and fire proof materials.

Making casts for statues etc.

Making patent plasters used for plastering fractured parts of the body.

ORGANIC COMPOUNDS

PURIFICATION AND CHARACTERIZATION

There are the following methods for purification of organic compounds.

(1) Crystallization (2) Fractional crystallization (3) Sublimation (4) Simple distillation (5) Fractional distillation (6) Distillation under reduced pressure (7) Steam distillation.

(1) **Crystallization.** In this method a suitable solvent is selected which can dissolve the main substance but not the impurity. The impure substance is dissolved in a minimum amount of the hot solvent so as to obtain in a saturated solution. Then the hot solution is filtered to remove insoluble im-

purity. The filterate is allowed to cool and the crystal can be separated by filteration.

(2) **Fractional crystallization.** This method used for separating two solids which have quite different solubilities in the same solvent. The less soluble crystallizes out first from a saturated solution and is separated from the mother liquor and on further concentration and cooling of the same liquor, the more soluble component crystallizes out.

(3) **Sublimation.** The change of a solid directly into vapour or heating and of the vapour into solid on cooling in known as sublimation. Sublimation is represented by:

$$\text{Solid} \underset{\text{Cooling}}{\overset{\text{Heating}}{\rightleftharpoons}} \text{vapour (or gas)}$$

Ammonium iodine, chloride, camphor, naphthalene sublime on heating and can be recovered in the form of a sublimate by cooling vapours. Mixture of sodium chloride and Ammonium chloride is heated in a China dish. On heating the mixture ammonium

chloride changes into vapours. These vapours condense on the cold inner side of the funnel to give back solid ammonium chloride. Iodine is purified by sublimation.

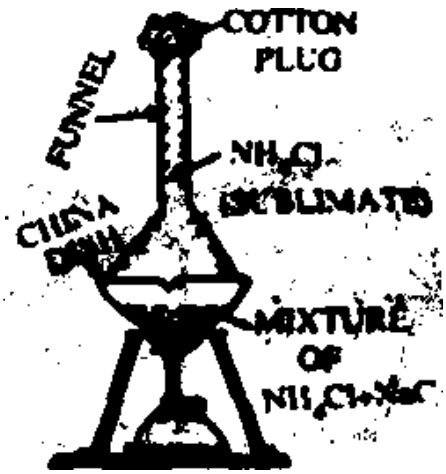


Fig.

(4) Simple distillation. Distillation is process of heating a liquid to form vapours and then cooling the vapour to get back the liquid, i.e.

$$\text{Liquid} \underset{\text{Cooling}}{\overset{\text{Heating}}{\rightleftharpoons}} \text{vapour (or gas)}$$

A mixture of common salt and water is taken in the distillation flask and heated. The forms vapours (steam) which rises up and comes out into the water condenser. Cold

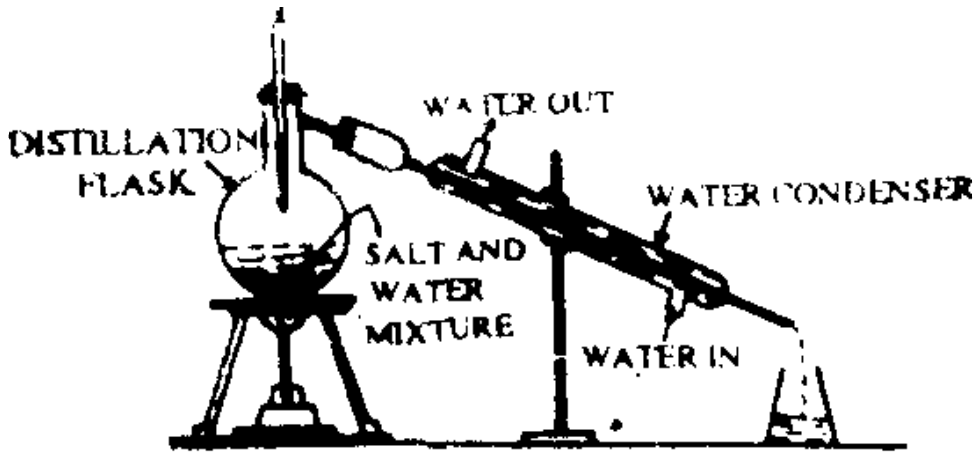


Fig.

water is circulated through the outer tube for cooling. Water vapours get cooled in the condenser and give back pure water.

(5) **By fractional distillation.** Fractional distillation is a process of separating two (or more) miscible liquids by distillation., the distillate being collected in fractions boiling at different temperatures. The separation of two liquids by fractional distillation is based

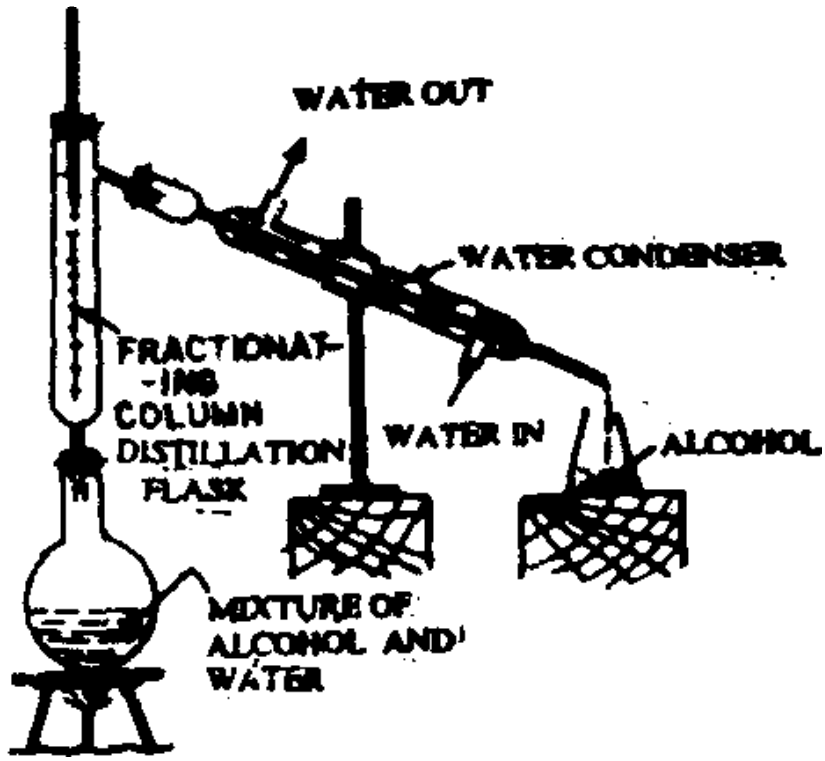
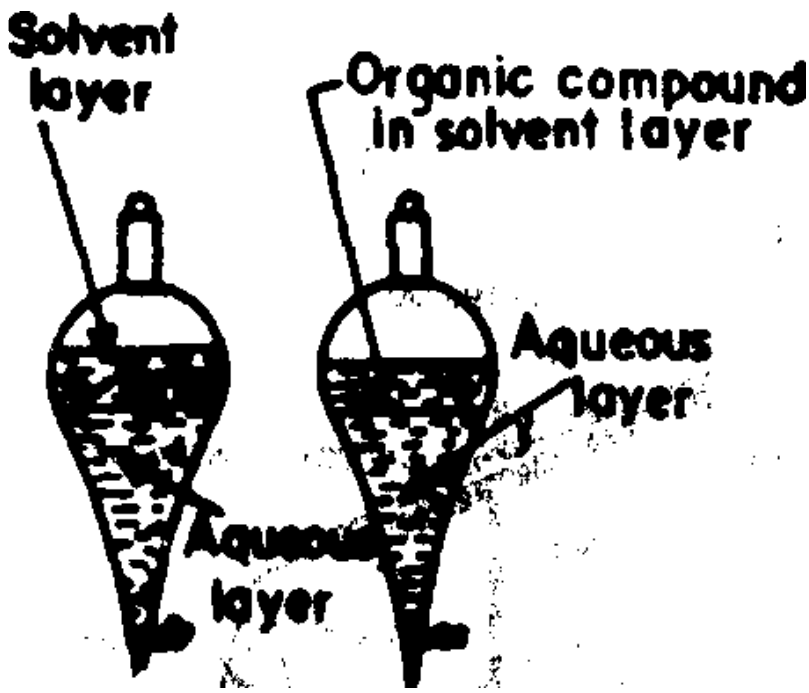


Fig.

on the difference in their boiling points. A mixture of alcohol and water can be separated by fractional distillation.

(6) **Distillation under reduced pressure.** If distillation is carried out at a lower



pressure (mean lowering of boiling point) the substance can distill undecomposed. For this a vacuum pump is used for lowering the pressure. The receiver consists of a distillation flask the side of which is connected to a pump through a manometer. This process helps in economising fuel in industrial activities since the liquid is made to boil at lower temperature.

(7) **Steam distillation.** This method Steam is passed through a heated flask containing the liquid to be distilled. The mix-

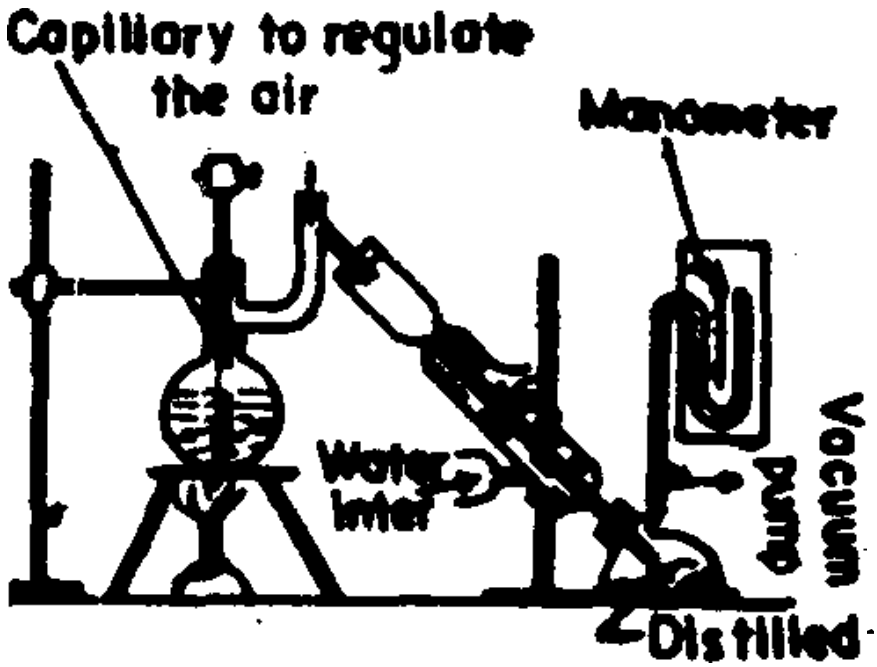


Fig.

ture of steam and vapours of the substance are condensed and the components are separated from each other. This method is used to those compounds which are steam volatile and sparingly soluble in water *e.g.*, aniline $C_6 C_5 NH_2$.

Detection of carbon and hydrogens. If a mixture of organic compounds and cupric oxide is heated strongly, carbon of the compounds gets oxidised to carbon dioxide gas, which turbids the lime water on passing through it. H_2 of the organic compound at

the same time gets oxidised to water, which can be absorbed on some anhydrous metallic salt (anhydrous $CuSO_4$ is white where as hydrated $CuSO_4$ is blue in colour).

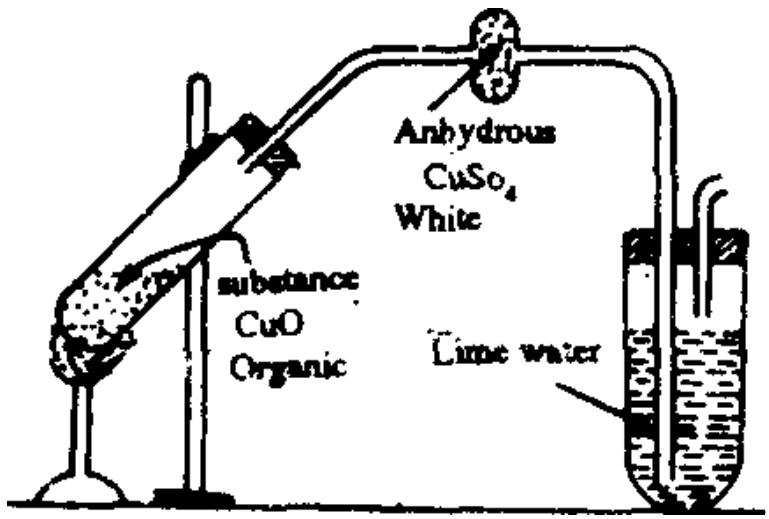


Fig.

$$C(s) + 2CuO(s) \rightarrow CO_2(g) + 2Cu(s)$$

$$2H(s) + CuO(s) \rightarrow H_2O\,(g) + Cu(s)$$

$$CO_2 + Ca(OH)_2\,(aq) \rightarrow \underset{\text{white}}{CaCO_2(s)} + H_2O(l)$$

$$\underset{\text{white}}{H_2O\,(g) + CuSO_4} \rightarrow \underset{\text{blue}}{CuSO_4\ 5H_2O(s)}$$

Test for nitrogen. The filterate is heated with $FeSO_4$ solution when sodium ferrocyanide is formed. Some Fe^{2+} is oxidised to Fe^{3+}. This solution on neutralization with dilute H_2SO_4 gives prussian blue colour due to formation of ferric ferrocyanide. If the organic substance contains both sulphur and nitrogen, it forms sodium sulphocyanide on fusion with sodium. The sulphocyanide solution gives a blood-red coloration with $FeCl_2$ solution.

Test for sulphur. In the absence of nitrogen, sodium sulphide present in the lassaigne's solution is detected by the following tests:

(i) To the second portion of lassaigne's solution is added sodium nitro-prusside solution. A purple violet coloration is obtained.

(ii) To a small quantity of lassaigne's solution is added acetic acid and lead acetate solution, when a black ppt. is formed.

Detection of phosphorous. Its presence is detected by fusing the compound with an oxidising mixture of sodium carbonate and potassium nitrate or with sodium peroxide alone when an alkali phosphate is formed. The fused mass is extracted with water and filtered. The filterate containing sodium phosphate is heated with conc. HNO_3 and an excess of ammonium molybdate solution is added. A yellow ppt. or coloration is formed if phosphorus is present. This yellow ppt. is of ammonium phosphomolybdate.

Empirical formula. The empirical formula of a compound may be defined as the simplest formula which gives the relative number of atoms of each element present in one molecule of the compound. The empirical formula of the compound glucose ($C_6H_{12}O_6$) for example is CH_2O which shows that C,H,O are present in the ratio of 1:2:1.

Setps in writing the empirical formula.

(1) The percentage of elements are

added together, the sum should be very close to 100.

(2) The mass percentages of elements are divided by the respective atomic masses to get the ratio of atoms by numbers.

(3) If the ratio numbers at this stage are not whole numbers, they are all multiplied by a suitable number to convert all of them to whole numbers.

(4) These numbers are divided by smallest number amongst them. This gives the simplified ratio by numbers.

(5) These whole numbers are then placed on the right bottom side of the symbols of elements to get the empirical formula of the substance.

Molecular formula. The molecular formula of a compound may be defined as the formula which gives the actual number of atoms of each element present in one molecules of the compound.

ALKYL AND ARYL HALIDES

Alkyl halides. is a halogen containing organic compounds. When a hydrogen atom of the saturated hydrocarbon is replaced by a halogen an alkyl halide is formed e.g., $C_nH_{2n+2} + X_2 \rightarrow C_nH_{2n+1}HX$ (X= halogen atom.). They are mono, di, tri etc., halogen derivatives according to the number of halogen atoms in the molecule. The simplest alkane methane (CH_4) forms four halogen derivatives by replacement of one, two, three or all the four hydrogen atoms by halogen atoms.

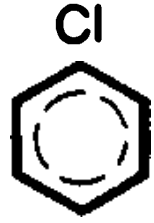
CH_3Cl	chloromethane
CH_2Cl_2	dichloromethane
$CHCl_3$	trichloromethane

CCl_4 tetrachloromethane

The higher derivatives are further classified into primary, secondary or tertiary depending upon the number of hydrocarbon attached to the carbon atom that holds the halogens.

Aryl halides are those compounds in which the halogen atom is directly attached to the aromatic ring. The halogen derivatives of aromatic hydrocarbons are of the two types.

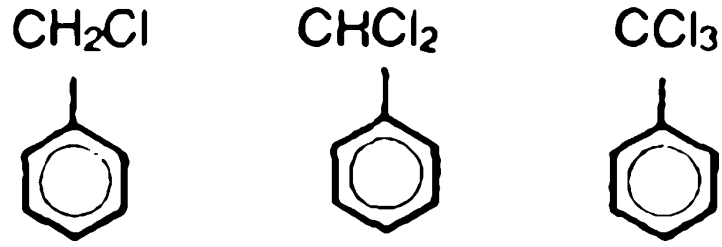
(1) **Ring substituted derivative.** In such compound the halogen atom is directly attached to the aromatic ring e.g., in chlorobenzene, Cl_2 is attached to the aromatic ring. Such halides are denoted as ArX



chlorobenzene

(2) **Side chain derivative.** In such molecule, the halogen atom is attached to a carbon atom in the side chain attached to an

aromatic ring e.g. the derivatives of toluene in which hydrogens of methyl group (side chain) are replaced by halogens are named as.



benzyl chloride — benzal chloride — benzotri chloride

Methods of preparation of alkyl halides

From hydrocarbons (by direct halogenation)

$$CH_4 \xrightarrow{Cl_2} CH_3Cl \xrightarrow{Cl_2} CH_2Cl_2 \xrightarrow{Cl_2} CHCl_3 \xrightarrow{Cl_2} CCl_4$$

673K

By the addition of halogen acids to alkanes. Alkyl halides are obtained when halogen acid act upon alkanes. The addition takes place slowly and follows Markownikoff's rule

$$CH_2 = CH_2 + HBr \rightarrow CH_3CH_2Br$$

ethylene ethyl bromide

A mixture of mono and polyhalogen derivatives are obtained which is difficult to separate such mixtures.

From alcohols. (a) It is prepared by the action of halogen acids on alcohol in presence of dehydrating agent ($ZnCl_2$ or H_2SO_4) which prevents the backward reaction.

$$CH_3CH_2OH + HCl \xrightarrow{ZnCl_2} CH_3CH_2Cl + H_2O$$

ethyl alcohol ethyl chloride

By the action of PCl_5 or PCl_3 on alcohols

$$C_2H_5OH + PCl_5 \rightarrow C_2H_5Cl + POCl_3 + HCl$$

Properties of alkyl halides

Nucleophilic displacement reaction: Electron rich reagents (nucleophiles) attack the alkyl halides and the weakly halide ion is displaced

$$\rightarrow C^{\delta+} - X^{\delta-} + Z \rightarrow \rightarrow C - Z + X$$

Several important products can be ob-

tained by suing different types of nucleophiles and alkyl halides.

With KI, an iodide is produced

$$C_2H_5Br + KI \rightarrow \underset{\text{ethyl iodide}}{C_2H_5I} + KBr$$

With ammonia, amines are produced

$$C_2H_5I + NH_3 \rightarrow \underset{\text{ethyl amine}}{C_2H_5NH_2} + HI$$

With alcoholic KCN, cyanides are formed

$$C_2H_5Br + KCN \rightarrow \underset{\text{ethyl cyanide}}{C_2H_5CN} + KBr$$

With KNO_2, nitro alkanes are produced

$$CH_3Br + KNO_2 \rightarrow \underset{\text{nitromethane}}{CH_3NO_3} + KBr$$

With alkoxide or alcohol, an ether is produced

$$C_2H_5Br + NaOC_2H_5 \rightarrow \underset{\text{diethyl ether}}{C_2H_5—O—C_2H_5} + NaBr$$

$$CH_3Cl + HOC_2H_5 \rightarrow \underset{\text{methyl ethyl ether}}{CH_3—O—C_2H_5} + HCl$$

With AgCN, alkyl isocyanide is formed

$$C_2H_5I + AgCN \rightarrow C_2H_5N{\equiv}C + AgI$$

ethyl isocyanide

Hydrolysis. One treatment with aqueous KOH or NaOH or moist Ag_2O an alcohol is produced

$$CH_3CH_2Br + NaOH \rightarrow CH_3CH_2OH + NaBr$$

Reduction. Alkyl halides are easily reduced to alkanes by nascent hydrogen in the presence of nickel catalyst

$$C_2H_5Cl + 2H \xrightarrow{Zn + HCl} C_2H_6 + HCl$$

ethane

Reaction with sodium. When an alkyl halide reacts with sodium metal in dry ether, a hydrocarbon is produced. This is called Wurtz reaction.

$$RX + 2Na + RX \xrightarrow{\text{ether}} R - R \rightarrow 2NaX$$

$$CH_3I + 2Na + ICH_3 \rightarrow CH_3{-}CH_3 + 2NaI$$

ethane

$$CH_3CH_2Br + 2Na + BrCH_2CH_3 \rightarrow CH_3CH_2CH_2CH_3 + 2NaBr$$

Butane

Dehydro halogenation. When treated with alcoholic KOH, alkyl halides produce alkenes

$$CH_3CH_2Cl + KOH \xrightarrow{\text{alcohol}} CH_2 = CH_2 + KCl + H_2O$$

ethane

when treated with aqueous KOH they produce alcohols

$$CH_3CH_2Cl + KOH \xrightarrow{\text{aqueous}} CH_3CH_2OH + KCl$$

Reaction with magnesium. An etheral solution of an alkyl halide dissolves magnesium metal forming

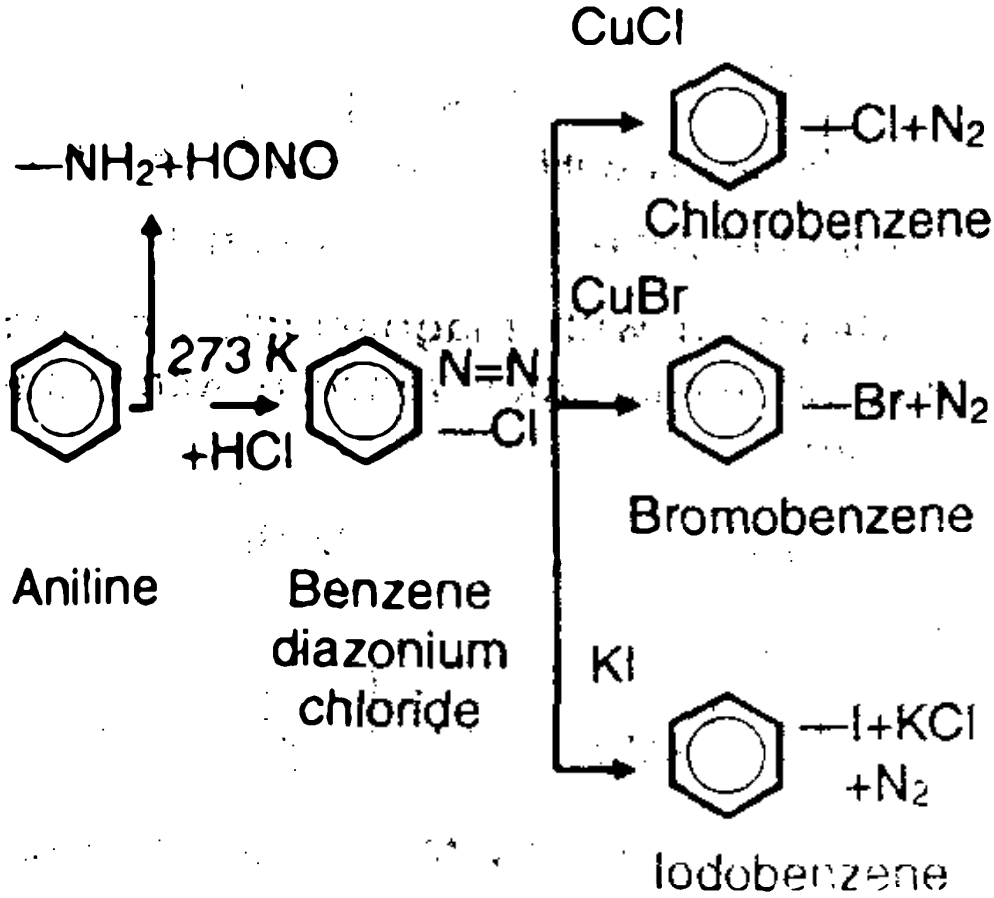
Grignard's reagent, R—Mg—X

$$CH_3CH_2Br + Mg \xrightarrow{\text{ether}} CH_3CH_2MgBr$$

ethyl magnesium bromide
(Grignard's reagent)

Preparation

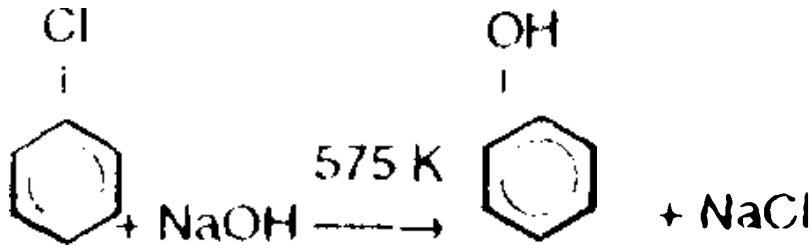
The dizonium salt is obtained by treating an amino compound with nitrous acid at low temperature. The dizonium salt so obtained react with CuCl, CuBr to form the corresponding aryl Halide. The aryl iodide is obtained when diazonium salt is reacted with potassium iodide.



These reactions are known as sandmeyer's reactions.

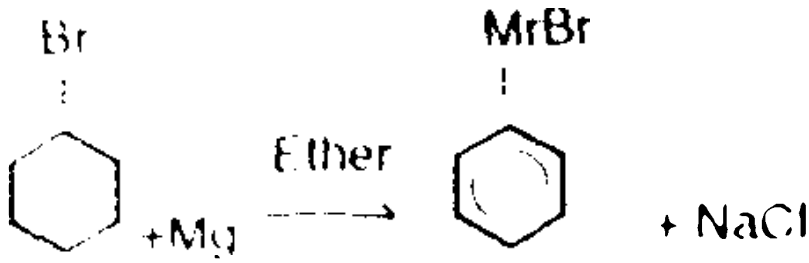
Properties of aryl halides.

Reaction with sodium hydroxide. Upon reaction with conc. NaOH solution at 575 K under pressure, the halogen atom is replaced by a hydroxyl group.



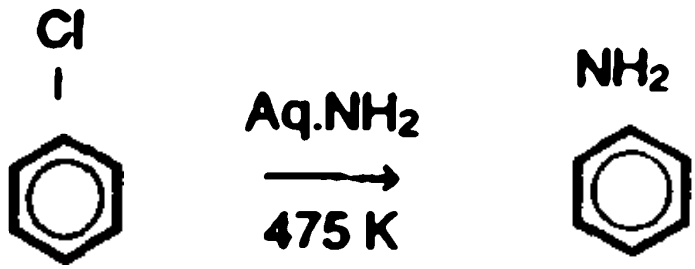
Chloro-benzene Phenol

Reaction with magnesium. Grignard reagent results upon reaction with magnesium

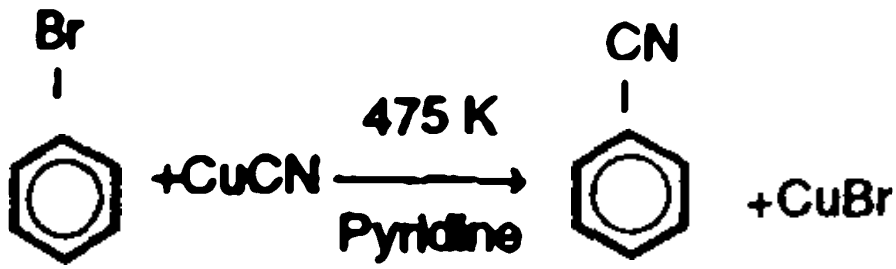


Phenyl Magnesium Bromide

Reaction with ammonia. When the aryl halide reacts with aqueous ammonia at 475 K then in the pressure of catalyst aniline is formed.



Reaction with cuprous cyanide. With CuCN, aryl cyanide is produced.



Phenyl cyanide

Reaction with sodium. When an etheral solution of aryl halide and sodium react, higher aromatic hydrocarbon is produced. This is called as Wurtz reaction.

Biphenyl

Preparation of chloroform. Pure chloroform is obtained when a mixture of acetone and bleaching powder are allowed to react i.e.—

$$CH_3COCH_3 + 3Cl_2 \rightarrow CCl_3COCH_3 + 3HCl$$

acetone — trichloro acetone

$$2CCl_3COCH_5 + Ca(OH)_2 \rightarrow 2CHCl_3 + (CH_3COO)_2Ca$$

chloroform — cal. acetate

It can be obtained by the partial reduction of carbon tetrachloride

$$CCl_4 + 2H \xrightarrow[\text{Iron powder}]{Sn + HCl \text{ or}} CHCl_3 + HCl$$

Properties of chloroform:

It is a colourless liquid and heavier than water and boils at 334 K.

In water it is partially soluble but completely soluble in ethanol and ether.

In the presence of air and sunlight, chloroform is slowly oxidised to produce poisonous phosgene or carboxyl chloride gas

$$CH_3Cl + (O) \rightarrow \underset{\text{Phosgene}}{COCl_2HCl}$$

Reduction.

$$CHCl_3 + 2(H) \xrightarrow{Zn/HCl} \underset{\text{in ethanol}}{CH_2Cl_2} + HCl \quad \text{Methyl chloride}$$

Methane is formed when $CHCl_3$ is reduced with zinc and water

$$CHCl_2 + 6[H] \xrightarrow{Zn/H_2O} CH_4 + 3HCl$$

With nitric acid. Conc. HNO_3 gives chloropicrin upon heating

$$CCl_3H + HONO_2 \quad \underset{\text{Chloropicrin}}{Cl_3C(NO_2)} \quad + H_2O$$

Chloropicrin is used as an insecticide and war gas.

With silver powder. Upon warming, acetylene results.

$$2CHCl_3 + 6Ag \rightarrow \underset{\underset{CH}{||}}{CH} + 6AgCl$$

Uses of chloroform. As laboratory reagent and in medicine. As preservative for anatomical specimens.

As an anaesthetic. As a solvent for fats, waxes etc.

Iodoform (CHI_3). is obtained by the action of iodine on ethyl alcohol or acetone in the presence of an alkali.

$$C_2H_5OH + 4I_2 + 6NaOH \longrightarrow$$
$$CHI_3 + HCOONa + 5NaI + 5H_2O$$
Iodoform

HYDROGEN PEROXIDE & WATER

Rain water contains dissolved gases and substance in suspension Sea water contains dissolved solids (chiefly NaCl) and compounds of 72 elements. Tap water contains chlorides and sulphates of Ca, Mg, Na etc. Distilled water is relatively free from the impurities.

Abnormal properties of water are as follows:

High density; High specific heat; High dielectric constant of water; High value of heats of vaporisation and fusion.

There are two types of water

Hard water. Which does not form lather with soap solution easily is known as hard water.

Soft water. which produces lather with soap solution is called soft water.

Responsibility for hardness of water. Calcium and magnesium ions in the form of dissolved salts such as bicarbonates, chlorides and sulphates are responsible for hardness of water.

Types of hardness. There are two types of hardness (i) temporary hardness (ii) permanent hardness.

Temporary hardness is due to the pressure of bicrabonate ion (HCO_3^-) in addition to Ca^{2+} and Mg^{2+} ions. This hardness can be removed merely by boiling when insoluble carbonates are precipitated off.

$$Ca^{2+} + 2HCO_3 \rightarrow CaCO_3 + H_2O + CO_2$$

Permanent hardness. Presence of soluble salts of calcium and magnesium other than bicarbonates (usually chlorides and sulphates) are the causes of this hardness and which cannot be removed merely by boiling.

Softening of hard water. Conversion of hard water into soft water is termed soften-

ing. Hard water can be softened by following 3 ways

(i) by eliminating Ca^{2+} and Mg^{2+} as insoluble precipitates

(ii) by making these ions harmless or

(iii) by replacing these ions such as Na^{+}.

Removing temporary hardness.

By boiling. The dissolved bicarbonates are precipitated as insoluble carbonates which are filtered off.

$$Ca(HCO_3)_2 \xrightarrow{\text{Boil}} CaCO_3\downarrow H_2O + CO_2\uparrow$$

$$Mg(HCO_3)_2 \xrightarrow{\text{Boil}} MgCO_3\downarrow + H_2O + CO_2\uparrow$$

By adding lime $Ca(OH)_2$

$$Mg(HCO_3)_2 + Ca(OH)_2 \longrightarrow MgCO_3\downarrow + CaCO_3\downarrow + 2H_2O$$

Removing permanent hardness. Clark's method. By adding washing soda when Ca_{2+} and Mg^{2+} are precipitated as insoluble carbonates.

$$Ca^{2+} + CO_3{}^{2} \rightarrow CaCO_3\downarrow$$

$$Mg^{2+} + CO_3^{2-} \rightarrow MgCO_3\downarrow$$

By exchange of ions. Hard water is passed through minerals like (zeolite-sodium aluminium ortho silicate) or synthetic ion-exchange resin when offending Ca^{2+} and Mg^{2+} ions are replaced by harmless ions like Na^+ or H^+ which do not cause hardness.

$$Na_2Ze + Ca^{2+} \rightarrow CaZe + 2Na^+$$

Sod Zeolite Ca-zeolite

$$2R.COOH + Ca^{2+} \rightarrow (RCOO)_2Ca + 2H^+$$

Hard water unfit for drinking purpose. The Ca^{2+} ions and Mg^{2+} ions present is excess in hard water are harmful for human beings. Hence hard water is not good for drinking purpose.

Structure of water. In H_2O molecules, both H atoms are linked with the O atom by covalent bonds. The relative electronegative difference between O and H atom is large, the O—H is highly polar with the H atom forming the positive end of the bond. The water molecule is bent molecule with an angle of 105° between two covalent bonds.

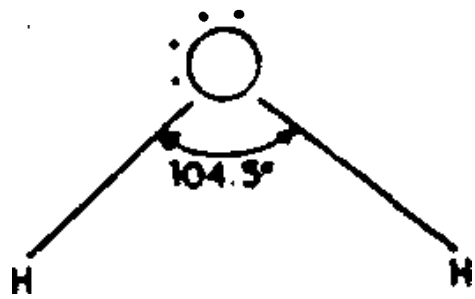


Fig.

Hydrogen bonding. The hydrogen bond may be defined as the weak electrostatic bond which binds hydrogen of one molecule with an electro-negative element (*O*, *N*, *F*) of another molecule.

Water molecule is strongly polar. The unsymmetrical arrangement of polar covalent bonds keeps the water molecule highly polar.

Condition for hydrogen bonding. The electronegativity of the atom to which hydrogen atom is attached should be high. The electronegative atom attached to the hydrogen should be small.

Ice is lighter than water. because ice has a open structure. When ice melts some of the hydrogen bonds are broken, so the

structure is less open. Thus the water molecules get packed more closely together causing water to have more density than it.

Water is a liquid and H_2S is a gas. Hydrogen bonding water molecules get associated and packed together hence the water is a liquid. There is no hydrogen bonds between H_2S molecules and the weaker vander waals forces are unable to keep H_2S molecules packed together. So H_2S is a gas.

Boiling point of HF is higher than that of H_2O. Both of them posses H-bond. But the hydrogen bond strength increases as the electronegativity of element increases. Thus bond strength of H—F is more than H—O bond, so H—F possesses higher boiling point than H_2O.

Preparation of Hydrogen Peroxide (H_2O_2)

From barium peroxide. Hydrated barium peroxide $BaO_2\ 8H_2O$ is added to ice-cold H_2SO_4.

$$BaO_2\ 8H_2O + H_2SO_4 \rightarrow BaSO_4\downarrow + H_2O_2 + 8H_2O$$

Phosphoric acid, H_3PO_4 can be used in place of H_2SO_4

$$3BaO_2 + 2H_3PO_4 \rightarrow Ba_3(PO_4)_2\downarrow + 3H_2O_2$$

From sodium peroxide. Na_2O_2 is added to ice-cold 20% sulphuric acid.

$$Na_2O_2 + H_2SO_4 \rightarrow Na_2SO_4 + H_2O_2$$

On cooling the solution sodium sulphate is crystallized out as $Na_2SO_4 . 10H_2O$. The clear solution is decanted off and distilled in vacuum when a 3% solution of H_2O_2 is obtained. This is known as Merck's process.

Electrolytic method. By electrolysis of cold conc. H_2O_2 can be obtained H_2SO_4 or ammonium sulphate plus H_2SO_4 solution at high current density.

$$H_2SO_4 \rightarrow H^+ + HSO_4^-$$

$$(NH_4)_2SO_4 + H_2SO_4 \rightarrow 2NH_4HSO_4$$

$$NH_4HSO_4 \rightleftharpoons NH_4^+ + HSO_4^-$$

Anode reaction

$$2HSO_4^- \rightarrow H_2S_2O_8 + 2e^-$$

Per-oxy (sulphuric acid)

Cathode reaction $-2H^+ + 2e- \rightarrow H_2$

Peroxy-sulphuric acid (from anode compartment) is hydrolysed.

$$H_2SO_4 + H_2O \rightarrow H_2SO_4 + H_2SO_5$$

$$H_2SO_5 + H_2O \rightarrow H_2SO_4 + H_2O_2$$

Concentration of H_2O_2 solution. A dilute solution of H_2O_2 is concentrated at low temperature (< 33 k) under reduced pressure to give 90% solution. on further concentrated by repeated fractional crystallization at about 263 K 100% H_2O_2 is obtained.

Strength of hydrogen peroxide. The bottles containing H_2O_2 are generally marked as 10 volumes, 20 volumes and so on. The bottle of 20 volumes shows that 1 ml of H_2O_2 solution at N. T. P. liberates 20 ml of oxygen.

H_2O_2 is colourless syrupy liquid with no smell of bitter taste.

it is miscible with alcohol water and ether in all proportions.

Chemical properties. H_2O_2 in pure form

Decomposition. is an unstable liquid. On heating or long standing, it decomposes to give water and oxygen.

$$2H_2O_2 \rightarrow 2H_2O + O_2$$

Acidic in nature. Conc. H_2O_2 is acidic to litmus, but its dilute solution in water is neutral towards litmus.

The following reactions prove this.

Action with hydroxide. It reacts with hydroxides to give peroxides.

$$2NaOH + H_2O_2 \rightarrow Na_2O_2 + 2H_2O$$

With carbonates. H_2O_2 reacts with carbonates with the evolution of carbon dioxide.

$$Na_2CO_3 + H_2O_2 \rightarrow Na_2O_2 + H_2O + CO_2$$

Action with potassium iodide solution.

$$H_2O_2 \rightarrow H_2O + O$$

$$2KI + H_2O + O \rightarrow 2KOH + I_2$$

$$2KI + H_2O \rightarrow 2KOH + I_2$$

Iodine is liberated.

Action with lead sulphide. It oxidises lead sulphide (black) to lead sulphate (white).

$$[H_2O_2 \rightarrow H_2O + O] \times 4$$

$$PbS + 4O \rightarrow PbSO_4$$

$$PbS + 4H_2O_2 \rightarrow PbSO_4 + 4H_2O$$

Action with arsenites.

$$H_2O_2 \rightarrow H_2O + O$$

$$Na_3AsO_3 + O \rightarrow Na_3AsO_4$$

$$Na_3AsO_3 + H_2O_2 \rightarrow Na_3AsO_4 + H_2O$$

Sold. Arsenite Sod. Arsenate

Arsenites are oxidised to arsenates.

Action with sulphites.

$$H_2O_2 \rightarrow H_2O + O$$

$$Na_2SO_3 + O \rightarrow Na_3SO_4$$

$$Na_2SO_3 + H_2O_2 \rightarrow Na_2SO_4 + H_2O$$

It oxidises sulphites to sulphates.

Action with nitrites.

$$H_2O_2 \rightarrow H_2O + O$$

$$KNO_2 + O \rightarrow KNO_3$$

$$KNO_2 + H_2O_2 \rightarrow KNO_3 + H_2O$$

It oxidises nitrites to nitrates.

Action with acidified ferrous sulphate. It oxidises ferrous sulphate to ferric sulphate

$$H_2O_2 \rightarrow H_2O + O$$

$$\underline{2FeSO_4 + H_2SO_4 + O \rightarrow Fe_2(SO_4)_3 + H_2O}$$

$$2FeSO_2 + H_2SO_4 + O \rightarrow Fe_2(SO_4)_3 + 2H_2O$$

Bleaching property. It is used to bleach silk, wool, feather, ivory etc. H_2O_2 bleaches substances by oxidation.

$$H_2O_2 \rightarrow H_2O + O$$

Coloured compound + O → Colourless compound.

Due to its oxidising nature, it is good germicide and disinfectant also. It behaves as a reducing agent. Some important reduction reaction of H_2O_2 are:

With ozone. It reacts with ozone to form water and oxygen. Ozone is reduced to oxygen.

$$H_2O_2 + O_3 \rightarrow H_2O + 2O_2$$

Action with silver oxide. Silver oxide is reduced to silver metal.

$$H_2O_2 \rightarrow H_2O + O$$

$$Ag_2O \rightarrow 2Ag + O$$
$$O + O \rightarrow O_2$$
$$Ag_2O + H_2O_2 \rightarrow 2Ag + H_2O + O_2$$

With halogens. It reduces halogens to corresponding halogen acids.

$$Cl_2 + H_2O_2 \rightarrow 2HCl + O_2$$

Following are the uses of hydrogen peroxide—

For bleaching delicate materials like silk, wool, straw, hair etc.

As antiseptic for washing wounds, teeth and ears under the name of per hydrol.

For restoring the colour of lead paintings.

THE OXYGEN FAMILY

Group VI A. The elements oxygen (O), selenium (Se), sulphur (S), tellurium (Te) and polonium (Po) are in the group VIA of the periodic table, the first four members of this group are non-metallic in nature and the last member of this family (polonium is a radio-active element with a very short life).

Electronic configuration. All these elements have the s^2p^4 valence electron configurations. They have a tendency to accept two electrons from other elements as they are very near to noble gas and form divalent anions such as O^{2-}, S^{2-} and thus perform noble gas configuration.

Element	*Atomic number*	*Electronic configuration*
Oxygen	8	[He] $2s^2$ $2p^4$
Sulphur	16	[Ne] $3s^2$ $3p^4$
Selenium	34	[Ar] 3d 10 4s2 4p4
Polonium	84	[Xe] $4\int^{14}$, $5d^{10}$, $6s^2$ $6p^4$
Tellurium	52	[Kr] $4d^{10}$ $5s^2$ $5p^4$

Trends in physical properties

Ionisation energy decreases regularly from oxygen to polonium (because atomic size increases).

Density, m p., b.p., atomic value and ionic radii increase regularly with atomic number down the group from oxygen to tellurium.

Electronegativity decreases regularly with the atomic number down the group from oxygen to Po, i.e., 3.5, 2.5, 2.4, 2 and 1.75.

Molecular structure. Oxygen exist as diatomic molecule O_2 but other elements exist as polyatomic molecules, (S_8).

Allotropy is shown by all elements. e.g., oxygen as O_3 and O_8, sulphur as rhombic, monoclinic, plastics etc.

Catenation is formation of chain of similar atoms. (H—O—O—H, H—S—S—H, H—S—S—S—H. etc.

Oxides. All elements form variety of oxides.

Sulphur	*Selenium*	*Tellurium*	*Name*
SO	—	TeO	Monoxide
SO_2	SeO_2	TeO_2-	Dioxide
SO_3	SeO_3	TeO_3	Trioxide
S_2O_7	—	—	Heptoxide

Oxygen molecules are diatomic, whereas other members form polyatomic molecules e.g. sulphur remains as S_8.

The compounds of oxygen are more ionic than those of others.

Oxygen at room temperature is a gas whereas all other members are solid.

Oxygen forms strong hydrogen bonding, which other members do not form.

Oxygen is paramagnetic, while other members are not. They are diamagnetic.

Oxygen shows an oxidation state of — 2 only. The other members of family exhibit +2, +4, +6 oxidation states also as shown above.

Oxygen atoms has a small size.

Electronegativity of oxygen is high.

Nonavailability of vacant d-orbitals in oxygen. All these state forced the Oxygen to differ from other member. Examples are as follows.

Preparation of ozone. The conversion of oxygen to ozone is a highly endothermic reaction. $3O_2 + 280kJ = 2O_3$

Ozone

Since the ozone is thermally unstable, the required energy cannot be provided in the form of direct heat. In practice, this energy is provided by means of silent electric discharge in an ozonizer. A simple ozonizer (called Siemen's ozonizer) is shown in Fig-

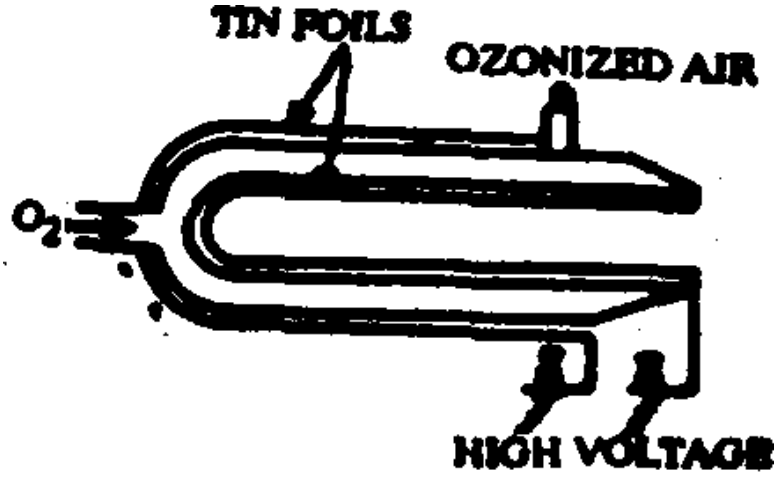


Fig.

ure. Oxygen is passed through the annular space between the two walls of a double walled glass tube.

*Metallic character increases while non-*metallic character decreases down the group. (Polonium is a metal).

Oxidation state. *Oxygen being the most* electronegative forms O_2 – ions and shows an oxidation state of [except in F_2O (+ 2) and H_2O (– 1).] Other elements show +2, +4 and +6 oxidation states due to promotion of electrons to vacant d-orbitals.

Trends. All the elements of group VI A form stable hydrides, H_2O, H_2S H_2Se, H_2Te and H_2PO. All these hydrides are

gases leaving water which is a liquid due to hydrogen bonding. All the hydrides are reducing agents except water. They are weakly acidic. The stability of hydrides decreases but their acidic character increases from H_2O to H_2Te.

The element of group VI A form a variety of halides in various oxidation states i.e., mono, di-tetra and hexa-halides. S, Se and Te show maximum valency in hexa fluorides e.g., SF_6, SeF_6 and TeF_6. These are formed by $sp^2 d^2$ hydridization and they have octahedral structures.

The outside of the outer tube is clud in a metal foil, and a cylinder of metal foil is likewise placed inside the inner tube.

The two pieces of metal foil are connected to the terminals of a 20,000—30,000 volts transformer. The yield is increased, however, if the temperature is kept low and the oxygen gas is thoroughly dried before being derived to the ozonizer.

Physical Properties. Unlike oxygen

Ozone is a faintly bluish gas has a very characteristic pungent ordour. Ozone is slightly soluble in water, but is easily soluble in carbon tetrachloride.

Chemical Properties. Ozone is more reactive than oxygen chemically. Some of the typical reactions are—

Oxidising action. Ozone acts as a powerful oxidizing agent, which may be attributed to the reaction. $O_3 \rightleftharpoons O_2 + O$

Thermal decomposition. Decomposition of ozone is a slow process, which can be accelerated by raising the temperature. The decomposition can be catalyzed by a variety of substances, such as platinum black, copper oxide etc.

$$2O_3 \xrightarrow{\text{Heat}} 3O_2$$

The nascent oxygen, infact acts as the oxidizing agent. Some of the typical oxidizing reactions are:-

Ozone liberates iodine from aqueous solution of iodides,

e.g. $2KI + H_2O_3 \rightarrow 2KOH + O_2 + I_2$

By adding a drop of starch solution, liberated iodine can be detected with which is gives deep blue colour.

I_2 + Starch → Intense blue colour

It liberates sulphur from H_2S gas or its solution.

$$H_2S + O_3 \rightarrow S + H_2O + O_2$$

White precipitate of lead sulphate is formed from black precipitate of lead sulphide.

$$PbS + 6O_2 \rightarrow PbSO_4 + 4O_2$$

Tailing of mercury when passed through mercury, mercury loses its meniscus and sticks to the walls of glass tube, due to the formation of Hg_2O, which dissolves in mercury. This phenomenon of mercury sticking to glass is called tailing of mercury.

$$2Hg + O_3 \rightarrow Hg_2O + O_2$$

Ozone reacts with organic compounds having double bond (C=C) or triple bond (C≡C) to give ozonides. These ozonides on

hydrolysis give aldehydes and ketones. This reaction is known as ozonolysis. Which is useful in fixing the position of double bond or triple bond in organic molecule.

Examples (i) Butene-1 on ozonolysis gives propanal and methanal,

$$CH_3\,CH_2\,CH = CH_2 + O_3 \rightarrow$$

$$CH_3\,CH_2\,CH(-O-CH_2)\text{ with O.....O bridge}$$

ozonide

$$CH_3\,CH_3\,CH(-O-CH_2)\text{ with O.....O bridge} + H_2O \rightarrow$$

$$CH_3\,CH_2\,CHO + HCHO + H_2O$$

Propanal methanal

Butene-2 ($CH_3\,CH = CH.\,CH_3$) on ozonolysis will give ethanal $CH_3\,CHO$ and ethanal CH_3CHO.

Test for Ozone. It blackens silver coin.

Bubble the gas through an aqueous solution of potassium iodide containing starch solution. Appearance of deep blue colour

confirms the gas to be ozone.

Uses. Ozone is used as a bleaching agent for bleaching oils, waxes etc. Bleaching action is due to the oxidation of the colouring matter.

It is also used for purifying air and sterilizing water and for ageing tobacco.

In the manufacture of artificial silk and synthetic camphor ozone is used.

SULPHUR

Production of sulphur dioxide. Sulphur dioxide is produced by burning sulphur or iron pyrites (FeS_2) in air.

$$S + O_2 \rightarrow SO_2$$

$$4FeS_2 + SO_2 \rightarrow 2Fe_2O_3 + 8SO_2$$

Manufacture of sulphuric acid. In this process SO_2 obtained by burning sulphur or pyrites is oxidized to SO_3 catalytically.

The SO_3, so produced is absorbed in conc, H_2SO_4 to obtain oleum. H_2SO_4 of any desired concentration can be obtained by reacting oleum with calculated amounts of water.

Purification of the gases. Gases (SO_2 and O_2) coming from the burner contain various impurities like sulphur, dust, arsenious oxide etc. These impurities must be removed because they poison the catalyst.

Catalytic oxidation of sulphur dioxide. In the contact process, sulphur dioxide is forced to unite with oxygen in the presence of a catalyst.

The catalyst, platinum, formerly used has now been replaced by vanadium pentaoxide.

$$2SO_2 + O_2 \xrightarrow[450\text{—}500^\circ\,C]{V_2O_5\ (catalyst)} 2SO_3$$

A good yield of SO_3 can be obtained under the following conditions:

Low temperature, 450° C, high pressure, 1-2 atmosphere, an excess of air or oxygen use of a catalyst.

This process is known as Le Chatelier's process. There are quite a few catalysts viz,

vanadium pentaoxide, finely divided platinum, mixture of ferric oxide and cupric oxide, but V_2O_5 is preferred, because it does not get poisoned so quickly.

Oleum Sulphur trioxide is dissolved in conc. H_2SO_4 forming oleum,

$$SO_3 + H_2SO_4\ O \rightarrow H_2S_2O_7 \text{ oleum}$$

Oleum, so obtained, in then diluted with water to get sulphuric acid of desired concentration.

$$H_2S_2O_7 + H_2O \rightarrow 2H_2SO_4$$

Water cannot be used for absorbing sulphur trioxide, since SO_3 gives dense fog with water $SO_3 + H_2O \rightarrow H_2SO_4$

(dense sulphuric acid fog)

Properties of Sulphuric Acid. Pure sulphric acid is a colourless, odourless oily liquid (m. p. 10.38° C, b.p. 335.5° C, density is 1.84 gm cm^3 at 20°C). It forms hydrates H_2SO_4. H_2O.

Chemical properties. Sulphuric acid is an acid. It is sour and turns blue litmus red.

Reaction with metals. Many metals like zinc, iron, Al, Sn, Mn etc, react with dil. H_2SO_4 to evolve hydrogen gas

$$Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$$

$$Zn + 2H_3O + \rightarrow Zn^{2+} + H_2 + 2H_2O$$

Reaction with alkalies. It neutralizes alkalies forming two series of salts.

$$NaOH + H_2SO_4 \rightarrow NaHSO_4 + H_2O$$

$$2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$$

It decomposes carbonates to evolve carbon dioxide gas

$$Na_2CO_3 + H_2SO_4 \rightarrow Na_2SO_4 + H_2O + CO_2$$

Sulphuric acid when hot and conc. is a powerful oxidising agent. It oxidises carbon and sulphur to their corresponding oxides,

$$C + 2H_2SO_4 \rightarrow CO_2 + 2SO_2 + 2H_2O$$

$$S + 2H_2SO_4 \rightarrow 3SO_2 + 2H_2O$$

It oxidises hydrobromic acid to bromine and hydriodic acid into iodine.

$$2Br + H_2SO_4 \rightarrow Br_2 + SO_2 + 2H_2O$$

$$2HI + H_2SO_4 \rightarrow I_2 + SO_2 + 2H_2O$$

Because of its strong affinity for water, this acid acts as a powerful dehydrating agent.

It charrs wood, paper and sugar.

$$C_{12}H_{22}O_{11} + H_2SO_4 \rightarrow 12C + H_2SO_4.\ 11H_2O$$

It evolves CO from formic and oxalic acid

$$HCOOH + H_2SO_4 \rightarrow CO + H_2SO_4.\ H_2O$$

$$(COOH)_2 + H_2SO_4 \rightarrow CO + CO_2 + H_2SO_4.\ H_2O$$

It turns blue vitriol white

$$CuSO_4.\ 5H_2O + H_2SO_4 \rightarrow CuSO_4 + H_2SO_4\ 5H_2O$$

blue → white

sulphuric acid is an important sulphonating agent as

$$C_6H_6 + HOSO_2\ OH \rightarrow C_6H_5\ SO_2OH + H_2O$$

Benzene sulphuric acid → Benzene sulphonic acid

Gases which do not react with sulphuric acid can be dried by passing over con-

centrated sulphuric acid. It may also be used to maintain anhydrous conditions by removing water formed during the reaction.

$$C_3H_5(OH)_3 + 3HNO_3 \rightarrow C_3H_5(NO_3)_3 + 3H_2O$$

Some organic compounds are manufactured by dehydration method,

$$2C_2H_5OH \xrightarrow{\text{conc. } H_2SO_4} C_2H_5{-}O{-}C_2H_5 + H_2O$$

diethyl ether

$$2C_6H_5Cl + CCl_3CHO \rightarrow Cl{-}C_6H_4{-}\underset{\displaystyle CCl_3}{\underset{|}{CH}}{-}C_6H_4 + H_2O$$

Uses. Sulphuric acid is used in the manufacture of hydrochloric, nitric, phosphoric and chromic acids.

In the isolation of elemental phosphorus.

In the manufacture of sodium carbonate, alum and many other compounds.

Dye-stuff's industry would not have been

there without sulphuric acid. It is used for sulphonation of many organic compounds.

Various nitrogen and phosphatic fertilizers are manufactured using sulphuric acid.

It is used for making paints, explosives and medicines.

It is used in the manufacture of certain plastics and synthetic fibre.

It is an important drying, dehydrating and laboratory reagent.

Sodium thiosulphate ($Na_2S_2O_3$). This is prepared by boiling sulphur with alkaline solution of sodium sulphite $Na_2SO_3 + S \rightarrow Na_2S_2O_3$.

The unreacted sulphur is removed by filteration and the filterate is subjected to crystallization.

Properties. Sodium thiosulphate crystals are colourless and melt at 48° C. The water of crystallization can be removed completely when heated to 215° C.

The oxidation state of sulphur in thiosulphate ion is +2.

The thiosulphate ion in the presence of acids (even weak acids, such as carbonic acid), decompose to give free sulphur and SO_2. $S_2O_3^{2-} + 2H^+ \rightarrow SO_2 + S + H_2O$

Thiosulphate ion is a strong reducing agent and gets oxidized even by moderate oxidizing agents such as iodine.

$$S_2O_3^{2-} + I_2 \rightarrow S_4O_6^{2-} + 2I^-$$

tetrathionate ion

It is due to above reaction that thiosulphate decolourizes iodine. Uses. Sodium thiosulphate is used as, a fixer in photography, an antichlor for removing last traces of chlorine from the bleached fabric, in extractive metallurgy (for gold and silver).

Sodium sulphite. Sodium sulphite is prepared by passing SO_2 gas in a solution of sodium carbonate until the solution is acidic. The solution of sodium bisulphite thus obtained is boiled with more sodium carbonate until no more CO_2 is evolved.

The resulting solution on crystallization gives crystals of $Na_2SO_3 7H_2O$

$$Na_2CO_3 + 2SO_2\ 2H_2O \rightarrow 2NaHSO_3 + H_2O + CO_2 \uparrow$$

$$2Na_2HSO_3 + Na_2CO_3 \rightarrow 2Na_2SO_3 + H_2O\ CO_2 \uparrow$$

Uses. It is used as a source of SO_2 which is a mild bleaching agent for sugar, silk and wool, as an antichlor, as a preservative for food stuffs. as a strong disinfectant for air, in the preparation of photographic developers, as an antiseptic.

It is added to water of boiler to prevent scale formation and corrosion.

SURFACE CHEMISTRY

Surface Chemistry. It is a boundary which separates the two materials.

Active centres. The active centre are thought to be dislocations, crystal edges and other surface irregularities.

Adsorption. This is a phenomenon of higher concentration of any molecular species at the surface than in bulk of a solid is known as adsorption. It is a surface phenomenon.

Adsorbate. The one that gets adsorbed is called adsorbate.

Adsorbent. The substance that adsorbs is called an adsorbent.

Desorption. The phenomenon of removal of an adsorbed substance from a

surface on which it is adsorbed is called as desorption.

Reason for adsorption. The surface of a solid has unsaturated valencies, unbalanced forces of various types such as **Van der Waals force** and **chemical bar forces.** A solid surface binds the absorbate molecules by any of these forces.

Sorption. It includes adsorption and absorption both.

Absorption. Uniform distribution of the molecules throughout the bulk of the solid or liquid.

Positive adsorption. When there is an increase in the concentration of absorbate on the surface relative to its concentration in the bulk phase, it is known as positive adsorption.

Negative adsorption. This is found in some liquid solutions. When the solute concentration is found to be less on the layer of the surface than in the bulk (interior) of the solution this is called negative adsorption.

Chemical adsorption. If the chemical forces or binding hold the molecules to the solid, then it is known as a chemical adsorption or chemisorption. This phenomenon may occur due to the unbalanced vacancies on the surface atoms of the absorbents. Chemical absorption is more permanent than physical adsorption.

Physical adsorption. If the physical forces such as **Van der Waal's** hold the molecules to the solid. It is said to be physical adsorption or physisorption. This type of adsorption is not **permanent.**

Adsorption depends on temperature of the system.

the nature of the adsorbent and adsorbate

the activation energy of the adsorbent solid

the partial pressure of the gas in the gaseous phase.

Adsorption isotherm. The amount of gas absorbed on the surface of a solid increases according to the pressure of the gas

Adsorption isobars. Adsorption is an exothermic process, hence extent of adsorption decreases with the increase of temperature.

Physical adsorption isobar shows a decrease in the extent of adsorption as the temperature rises, the chemical adsorption shows an increase in the beginning and then a decrease as the temperature rises. Initial increase is due to the fact that chemical adsorption also requires activation energy.

Freundlich adsorption isotherm. Freundlich introduced a mathematical relationship between the amount of the substance adsorbed and the pressure of adsorbate

Applications of adsorption

The principle of adsorption is used in gas masks. The process of adsorption is employed for the recovery and concentrations of the vitamins and other biological subst.

Due to the adsorption phenomenon, animal charcoal is used as a decoloriser in

the manufacture of cane sugar.

Adsorption forms the basis of chromatography.

Adsorption plays an important role in heterogeneous catalysis.

For controlling the humidities of rooms, the silica and alumina gels are employed as adsorbents.

In order to create high vacuum, a bulb of charcoal cooled in liquid air is connected to an evacuated vessel. Due to adsorption by charcoal, high vacuum is there.

Colloidal solution. is a heterogeneous system in which the size of the dispersed particles is between 10^{-5} cm and 10^{-7} cm e.g. soap solution.

Colloidal state. is the dispersion of two immiscible phases which give somewhat permanent heterogeneous system.

Lyophilic Colloids are those colloids in which particles of dispersed phase have a great affinity (or love) for the dispersion medium. e.g. glue, gelatin, starch etc.

Lyophobic Colloids are those colloids in which there is no affinity (or love) between particles of colloid and the dispersion medium. e.g., $Al(OH)_3$ Sol, Fe $(OH)_3$, As_2S_3 Sol.

Multi-molecular colloids consists of aggregates of atoms of small molecules with diameter less than 1 mm i.e. solution of Gold particles.

Macromolecular colloids consists of dispersed particles that are large molecules i.e. polymers e.g. Most of hydrophilic solutions.

Micelles. Colloidal solutions which behave as strong electrolytes at low concentrations but exhibit colloidal properties at higher concentration are known as **micelles.** Such substances are also known as associated colloids.

True solution. A homogeneous mixture of two or more substances in which the dissolved substances is dispersed as particles of molecular dimension (of size <10 A i.e. 10^{-7} cm) is known as molecular or

true solution (solution of sugar in water).

Suspension. This process a heterogeneous system containing large dispersed particles of size greater than 10^{-5} cm remain suspended in the medium. In this case the particles can be seen by naked eye.

Lyophobic solutions are those in which there is no affinity/interaction between the dispersion medium and the dispersed phase and such solutions cannot be prepared by bringing them in direct contact with each other gold sol, silver sol, arsenic sulphide solution in water.

Lyophillic solutions are those in which the dispersion medium possesses great affinity for the dispersed phase; consequently they have a tendency to pass directly into colloidal solution form, when dispersed phase is brought in contact with dispersion medium (starch, glue, gelatin and ager solutions in water).

Methods of preparation of solutions are as described below:

By double decomposition; By hydrolysis;

By oxidation; By reduction; By mechanical dispersion method.

Brownian movement. The random and continuous motion of colloidal particles in a dispersion medium is called Browinan movement. This eratic motion is result of constant bombardment of colloidal particles by the molecules of dispersion medium in all direction. These impart momentum to colloidal solution.

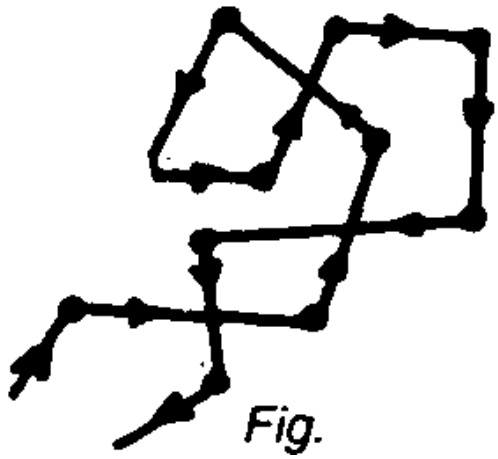


Fig.

Tyndall effect. Colloidal solution exhibit an interesting phenomenon. When a beam of light falls on a colloidal solution the path of beam is illuminated and is visible when viewed from the side. This is like dust particles floating in air becoming visible in a beam of light entering a dark room.

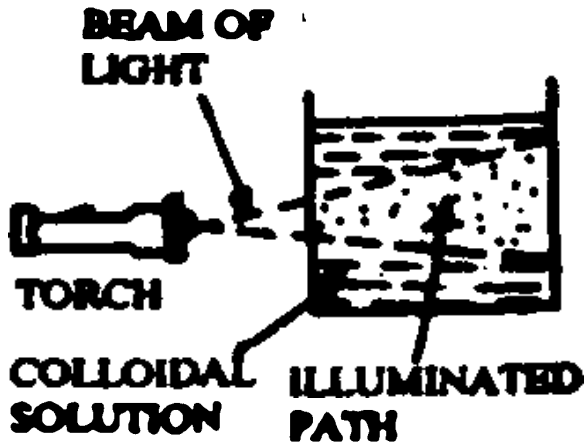


Fig.

This effect is the result of scattering of light by particles present in the colloidal solution and air.

This effect can be used to differentiate between a colloidal and a true solution.

Emulsions are liquid-liquid colloidal dispersion (milk is an emulsion of a liquid fat dispersed in water.)

Type of emulsion are as follows:

Water in oil type. In this type of emulsion, water is the dispersed phase and oil is the dispersion medium (e.g., Butter, cod liver oil cold cream etc.)

Oil in water type. In this type of emulsion dispersed phase is oil and the dispersion

medium is water (e.g., (i) milk in which fat is dispersed in water (ii) vanishing cream.)

Emulsification. Emulsions are prepared by agitating a mixture of two liquids into a colloidal mill.

Emulsifying agent or emulsifier. To stabilize an emulsion small quantities of substances are added. These substances are called emulsifying agents. These emulsifying agents are usually soaps, detergents and lyophilic colloids.

Several oil drugs are prepared in the form of emulsion

Many pharmaceutical and cosmetics, various lotions, cream and ointments are emulsions.

The digestion of fats in the intestines is helped by emulsification.

Concentration of the ore. The finally pulverized ore is treated with an oil emulsion and foams in such a way that the particles of the ore carried to the surface and then collected.

Hardy-schultz rule proves that ions carrying charge opposite to that of colloidal are effective in causing coagulation of a solution.

Coagulation efficiencies of electrolytes increases considerably with increase in valence of the ion curing coagulation. Thus for the coagulation of arsenic sulphide solution, the coagulating power decreases in order $Al^{3+} > Ba^{2+} > Na^{+}$.

Coagulation. Precipitation of a colloid through induced aggregation of its particles is known as **coagulations.** e.*g.* when $BaCl_2$ or $Al_2(SO_4)_3$ is added to arsenic sulphide solution or to ferric hydroxide solution coagulation occurs in each case.

Negatively charged particles of arsenic sulphide solution take up Ba^{2+} and then neutralize the charges by which particles colloide and thus coagulation occurs.

Demulsification. It is a process of breaking down an emulsion to yield constituent liquids. This can be brought by in one of the following physical methods.

Centrifugation, Filteration

Freezing

Electrostatic precipitation Boiling

Chemical methods to destroy the emulsifying agents (*e.g.*, cream is separated from milk by the centrifugation method.)

Catalyst. It is a substance which increases the rate of chemical reaction, without being used in reaction.

Homogeneous Catalysis. When the catalyst mixes homogeneously with the reactants and forms a single phase, the catalyst is said to be homogeneous. This kind of catalysis is known as homogeneous catalysis.

Example

$$SO_2\,(g) + O_2\,(g) \xrightarrow[\text{nitrogen}]{\text{oxides of}} SO_3\,(g)$$

Heterogeneous catalysis. When the catalyst forms a separate phase with the reactants then it is known as heterogeneous

catalyst. This type of catalysis is known as heterogeneous catalysis.

Example

Synthesis of CH_3OH from CO and H_2 using (ZnO + CuO) as catalyst.

Activity of catalysts: The ability of a catalyst to accelerate the rate of a chemical reaction is called activity of catalyst. Some times it may be as high as 10^{10} times.

Selectivity of catalyst refers to the ability of a catalyst to direct reactions to yield particular products *e.g.* n-heptane selectively gives toluene ($C_6H_5 - CH_3$) on Platinum catalyst.

Shape Selective Catalysts. The catalytic reactions depending on the pore structure of catalysts are known as shape selective catalysts. e.g. zeolite catalysts.

Zeolites: These are micro-porous alumino-silicates of the general formula $M_{x/n}[(AlO_2)_x (SiO_2)_y]$ m H_2O.

where n is the valence of cation M.

Comparison between enzymes and catalysts.

Catalysts	*Enzumes*
They increase or decrease reaction rate.	They generally increase reaction rate.
They are chemical substances which catalysis , chemical reactions.	They come from living cells , which catalysis biological reactions.
They are mostly inorganic metals and salts.	They are complex organic compound.
They, usually, act under high pressure and temperature.	They can act under mild conditions, usually under body temperature and atmospheric pressure.
They may or may not be specific.	They are highly specific.

They are employed in industrial preparation of chemicals.	They are essential for the life processes.
Usually catalysts in high concentrations are needed.	They always acts at a low concentrations.

Gold number. Gold number of used to measure the protecting powers of different colloids. It is the minimum number of milligrams of a protective colloid which when present in 10 ml of standard red gold solution, will just prevent the change of colour to blue on addition of 1 ml of 10% NaCl solution.

The smaller is the gold number of a lyophilic colloid, greater its protecting power.

Some values of gold numbers (in millions) are given below.

Protecting substance	*Gelatine*	*Egg Albumin*	*Gumarabic*	*Starch*
Gold number	0.005	0.08	0.15	25

Gel. is a colloidal solution in which a liquid is dispersed in high concentration form in a solid medium silica fruit, gel jams etc.

Preparation of colloidal solutions

Lyophilic Solutions. When the substances like gelatin, starch and high polymers etc. are warmed either with water or with suitable dispersion mediums, the lyophilic solutions are produced. The solutions thus obtained are stable and reversible.

Lyophobic solutions. For this the size of the particles of the dispersed phase is to be brought within the colloidal size range first and thus the process solutions obtained are comparatively unstable and irreversible.

Various methods used for the preparation of lyophobic solution are as follows.

By hydrolysis. When conc. solution of ferric chloride is added slowly to hot water and the solution is allowed to boil. A colloidal solution of ferric hydroxide is obtained due to hydrolysis.

$$FeCl_3 + 3H_2S \rightarrow Fe(OH)_3 + 3HCl$$

By oxidation. When hydrogen sulphide is bubbled sulphur is found to precipitate in the colloidal state by an oxidising agent such as bromine water or HNO_3.

$$Br_2 + H_2S \longrightarrow S + 2HBr$$

colloidal sulphur

By chemical reaction. When hydrogen sulphide gas is passed through a dilute solution of arsenious oxide in water. A colloidal solution of arsenic sulphide is obtained.

$$As_2O_3 + 3H_2S \longrightarrow As_2S_3 + 3H_2Br$$

Colloidal sulphur

By reduction. The method of reduction is used to prepare the colloidal solution of the metals like gold, silver and platinum from their salt solutions as described below.

Mechanical dispersion. In this process the coarsed particles are broken to the colloidal dimensions by the mechanical grinder (such as colloid mill). A protective colloid is added to stabilise the colloidal solution. For the preparation of Indian ink (colloidal sol), gum-arbaic is added as protective colloid.

Dialysis. The colloidal solution is taken in a parchment or cellophane bag and then suspended in running water in a trough. The impurities pass through the pores of the dialysis bag whereas the particles of the colloidal solution are left behind hence the colloidal solution remain inside the bag.

Electro-dialysis. The aforesaid process of dialysis can be hastened by keeping positive and negative electrodes in the water and then electric current is applied. This process is called electro-dialysis.

Ultrafiltration. Ordinary solutions pass through an ordinary filter paper due to its pores which is very large as compared with the size of colloidal particles.

The pores of the filter papers can be reduced by impregnating it with colloidal solution. These impregnated filter papers are known filters. Ultrafilters of desired pore size is obtained by adjusting the concentration of collodion.

Electrophoresis. The particles of the colloidal solution are electrically charged

either positive or negative.

The existence of the electric charge shown by the phenomenon of electrophoresis. It involves the movement of colloidal particles either towards the cathode or an anode under the influence of electric filed. Thus if arsenious sulphide solutions is taken in the U-tube, its particles move towards the anode.

Peptization is the process of dispersion of freshly formed precipitate by shaking it with dispersion medium.

NUCLEAR CHEMISTRY

Nuclear Chemistry. It is the branch of chemistry that deals with the changes in the nucleus.

Radioactivity. The phenomenon of spontaneous emission of powerful radiations as exhibited by heavy elements is called radioactivity.

Radioactive Elements. Those elements which exhibit the phenomenon of radioactivity are known as radioactive elements. e.g. Ra, U, Th etc.

Natural Radioactivity. If a substance emits radiations by itself, it is said to possess natural radioactivity.

Induced Radioactivity. If a substance does not possess radioactivity but starts emitting radiations on exposure to rays from

natural radioactive substance then it is said to possess induced radioactivity.

Particles emitted during radioactive decay

(i) α **-particles.** These are doubly ionised Helium atoms: These are positively charged particles ($_2^4He$) and can pass through 0.02 cm thick Aluminium foil.

(ii) β - **particles** consist of ordinary electrons ($_{-1}^0e$). They are negatively charged and can penetrate through 0.2 cm thick Aluminium foil.

(iii) γ - **particles** are high energy electromagnetic radiations with very short wave lengths. These are neutral and can pass through 1.00 cm thick Aluminium foil.

Group Displacement Law. During radioactive decay when α - particle is emitted the new element formed lies two columns to the left hand side, of the original element, in the periodic table and the mass of new ele-

ment formed is 4 units less than the parent element.

When a β -particle is emitted the new element formed lies one column to the right of the parent element in the periodic table and mass remains unchanged e.g.

$$^{238}_{92}U \longrightarrow {}^{234}_{90}Th + {}^{4}_{2}He \ (\alpha\text{-particle emission})$$

$$^{14}_{6}C \longrightarrow {}^{14}_{7}N + {}^{0}_{-1}e \ (\beta\text{-particle emission})$$

Radioactive Series. If, during radioactive disintegration, the daughter element is also radioactive then it decays further and the process continues till a stable isotope is formed.

This Chain of successive disintegration is known as radioactive series or disintegration series e.g.

$$^{234}_{91}Pa \longrightarrow {}^{234}_{92}U + {}^{0}_{-1}e$$

$$^{234}_{92}U \longrightarrow {}^{230}_{90}Th + {}^{4}_{2}He$$

Rate of Radioactive decay. It is given by

$$N_1 + N_0 . e^{-\lambda . t}$$

$$\text{or } \log \frac{N_0}{N_1} = \frac{\lambda . t}{2.303} \text{ or } \lambda = \frac{2.303}{t} \log \frac{N_0}{N_1}$$

where

N_0 = Number of radioactive nuclei present initially.

N_1 = Number of radioactive nuclei after time t

λ = disintegration constant.

Half-life Period. Half life period ($t_{1/2}$) of a radioactive material is the time in which a given amount of that material is reduced by disintegration to half the amount.

$$t_{1/2} = \frac{0.693}{\lambda}$$

where λ = disintegration constant.

(**Note:** Radioactive decay is a first order reaction)

$t_{1/2}$ is independent of amount of radioactive element initially present.

Longer the half-life period, more stable is the element.

Curie: It is the unit of activity i.e. rate of disintegration.

1 Curie = amount of radioactive element which gives 3.7×10^{10} disintegrations per second.

Another unit in use is **Rutherford.**

Radioactive Constant - (λ). It may be defined as the rate of disintegration when the number of radioactive nuclei present is one. It is also called **decay constant.**

unit for λ = sec, min, year etc.

Nuclear fission: The division of a nucleus into two approximately equal parts is called nuclear fission.

$^{235}_{92}U$ undergoes fissions as follows:

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{236}_{92}U \begin{cases} \rightarrow {}^{140}_{56}Ba + {}^{93}_{36}Kr + 3^{1}_{0}n \\ \rightarrow {}^{144}_{54}Xe + {}^{90}_{38}Sr + 2^{1}_{0}n \\ \rightarrow {}^{144}_{55}Cs + {}^{90}_{37}Rb + 2^{1}_{0}n \end{cases}$$

A large amount of energy is released during nuclear fission.

Atomic Bomb Principle. It is based on the principle of nuclear chain reaction.

Energy change in nuclear reaction. It is given by Einstein's energy-mass equation.

$$E = m c^2$$

where E is the energy equivalent of mass m and c is the velocity of light.

1 a.m.u = 931 Mev.

Nuclear Reactor is a plant in which nuclear fission is produced in the form of a controlled self-sustaining chain reaction.

It can be considered as a controlled chain reaction system supplying nuclear energy.

Breeder Reactor is an equipment that produced more fissionable nuclei than it consumes.

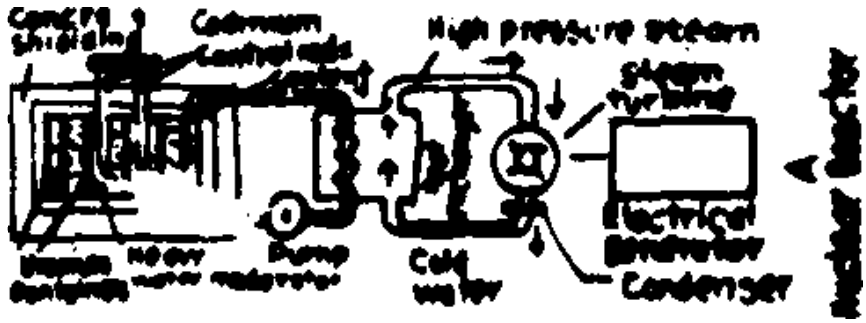


Fig.

Nuclear fusion. In nuclear fusion two or more light nuclei combine with the release of large amount of energy.

$$^{2}_{1}H + ^{2}_{1}H \longrightarrow ^{4}_{2}He + \text{energy}$$

$$^{1}_{1}H + ^{3}_{1}H \longrightarrow ^{4}_{2}He + \text{energy}$$

Sun is a source of continuous energy due to nuclear fusion of Hydrogen to Helium.

Carbon dating: It is a method used to determine the age of archeological objects (wood, dead plants and animals). It helps to determine the date at which plants and animals died.

Principle

$$^{14}_{7}N + ^{1}_{0}n \rightarrow ^{14}_{6}C + ^{1}_{1}H$$

$^{14}_{6}C$ (C – 14) has a $t_{1/2}$ = 5760 years

and decays as under

$$^{14}_{6}C \rightarrow ^{14}_{7}N + ^{0}_{-1}e$$

Older the sample, smaller is $_{6}{}^{14}$ C count rate.

Application of radioactivity and radioisotopes

(i) Co-60 is used to detect cracks and holes in components and to treat cancer.

(ii) Radioactive elements are used to generate electric power.

(iii) γ – rays are used for preservation of food.

(iv) C-14 trace technique is used for studying the mechanism of photosynthesis in plants.

BIOCHEMISTRY

Biochemistry is the study of the chemistry of life processes taking place in plants and animals.

Living system of life have highly complex structure and perform certion functions of life. Following features are the common to functioning of the living known creatures.

All living organism need energy for their growth and maintenance.

All living beings have independent function of their life.

Their energy need is met from either direct sunlight or from the energy released by the assimilation of foods.

They use simple raw materials to maintain their functioning.

The raw materials employed by living organisms are called nutrients.

The medium for various biochemical reactions is most water and has a pH around 7.

They usually carry on their activities at or near body temperature under atmospheric pressure.

All living system have the inherent capacity.

Biomolecules. Living system of every being are composed of several complex, lifeless substances which have specific functions. These molecules are known as biomolecules. The main class of biomolecules are carbohydrates, proteins and lipids.

Carbohydrates are polyhydroxy aldehydes (or ketones or substances) which hydrolyse to these. Carbohydrates (which mean hydrates of carbon) i.e.

Carbohydrates are polyhydroxy aldehydes (or ketones or substances) which

hydrolyse to these. Carbohydrates (which means hydrates of carbon) i.e.

Glucose or fructose —$C_6H_{12}O_6$ or $C_6(H_2O)_6$.

Carbohydrates are most important to all living organisms. Because they usually serve as cell and act as fuels to supply necessary energy the function of the living and their day's work.

Monosaccharides are the simplest carbohydrates and cannot be hydrolysed to small molecules. All monosaccharides contain either an aldehydic group (—CHO) or a ketonic group (=C=O).

e.g. Glucose — $C_2H_{12}O_6$ (an aldose)

Fructose — $C_6H_{12}O_6$ (aketone)

Disaccharide are those carbohydrates which yield two molecules monosaccharides on hydrolysis (sucrose, maltose etc.)

$$C_{12}H_{22}O_{11} + H_2O \rightarrow C_6H_{12}O_6 + C_6H_{12}O_6$$

Sucrose Glucose Fractose

Lipid. This term lipid is to denote biomolecules insoluble in water, but soluble

in organic solvents like chloroform and ether.

Oils and fats—Glycerides of higher fatty acids.

Phospho—lipids—Mixed glycordies of higher fatty acids and phosphoric acids.

Lipids play important role in living system as shown below—

Type of class of lipid	*Importance*
Oils and fats	Forms the greatest reservoir of energy for the animals.
Carotenoids	For producing colours in plants and animal materials.
Phospholipids	Have important role in biological oxidation processes

Vitamins are essential organic substances for regulating some of the body processes. Though required in quantities are vital

to life processes. Their absence leads to many diseases. The vitamins are essential constituents of food for continued health.

There are vitamins which are essential for living being. Their description is as below (Shown in a table).

Vitamins

Chemical nature	*Source*	*Deficiency diseases*
1. Vitamin A. Carotene derivative soluble in fats and oils but not soluble in water.	Ghee, Egg, liver, cod liver oil, green vegetables Milk, butter.	Retarded growth, lower resistance to infection, night blindness.
2. Vitamin B_1. Thiamine soluble in water but destroyed by heat.	Vegetables, yeast unpolished rice, milk	Loss of apetite, berbert.

3. Vitamin B_2. Rivoflavin water-soluble and resistance to heat.	Vegetable, unpolished rice, liver, milk.	Sore tongue, cracked lips, premature ageing, pellagra.
4. Vitamin B_6. Pyridoxine.	Cereal grains, yeast.	Nervous disturbance, convulsions.
5. Vitamin B_{12}. Cyanocoba-lamin water soluble and containing cobalt.	Found only in animals and micro-organism and not in plants.	Bad form of anaemia.
6. Vitamin C. Ascorbic acid water-soluble but destroyed by cooking and by air.	Lemons, grapes, tomatoes, oranges, cabbage, leafy vegetables, amala.	Pyorrhoea (in teeth) anaemia, pain in joints, scurey
7. Vitamin D. Soluble in fats and oils, inso-luble in water.	Egg, liver, meat, milk.	Rickets deformation of bones and teeth.

8. Vitamin E. α-toco-phenol soluble in fats and oils and insoluble in water.	Egg, wheat, gram, milk, ghee.	Loss of sexual power.
9. Vitamin K. Soluble in fats and not soluble in water	Oils, leafy vegetable, fish, meat.	Impaired clotting to blood, haemorrhage.

Harmones are biomolecules which are made in ductless (endocrine) glands and in body if disturbed, may lead to abnormal metabolic processes like goitre, diabetes and may even may cause inbalance in sexual harmones resulting "malformation" of sex organs.

Some important harmones are as follows

Harmone	*Organs of secrenion*	*Function*
1. Thyroxin	Thyroid	Stimulates metabolism

2. Testosteron	Testis	Natural functioning of female sex organ
3. Estrone	Ovary	Natural functioning of female sex organ
4. Proges-terone	Ovary	Natural functioning of menstrual cycle
5. Insulin	Pancreas	Metabolism of glu-cose
6. Glucagone	Pancreas	Increase blood glu-cose
7. Adrehaline	Adrenal medula	Increases pulse rate and blood pressure; releases glucose from glycogen and fatty acids from fats
8. Pituitary harmone	Pituitary gland	Stimulates adrenal cortex, gland, testis, overies and thyroid

These harmones play an important role in regulating many metabolic process and sex characteristics in living system.

There is a difference between Harmones and vitamins as shown below.

Vitamins	*Hormones*
(i) They are supplied to the body mainly from the food.	They are secreted or synthesised by the body's own glands.
(ii) They are essential for growth etc.	They take part in metabolic activities.
(iii) They give energy to the body.	They do not provide any energy to the body.

Proteins are nitrogeneous organic compounds of high molecular weights synthesised by plants and animals which on hydrolysis by enzymes gives amino acids.

Chemically, proteins are polymeric amides, derived from α-amino carboxylic acids.

Role of proteins. The important role played by proteins in living cells are as follows—

In regulation of metabolism.

In maintaining of fluid balance

In oxygen transport mechanism (by

haemoglobin)

In genetics

In structural sense of membrane etc.

RNA. (Ribonuleic Acid) is a polynucteotide consisting of (i) ribose (a pentose) as the sugar and (ii) uracil as the base in its structure.

DNA (Deoxyribonuclic Acid) is a polynucleoticle consisting of (i) deoxyribose (a pentose) as the sugar and (ii) adenine, guanine thyamine or cystosine as the base in its structure.

Comparison of DNA and RNA

DNA	*RNA*
It is mostly found in the nucleus.	It is found in the nucleous, cytolam and chromosomes.
It has deoxyribose sugar.	It has ribose sugar.

It is only of one type	It is found in three forms: (i) mersonger—RNA (ii) ribosomal—RNA (iii) transfer—RNA
It contains the bases, adenine, cytosine and thyamine.	It contains the bases adenine, guonine and uracil.
It is the main genetic material of enkaryortic cells.	It is the genetic material of plant viruses.
It controls the "transmission of hereditary characteristics.	It controls the synthesis of proteins in the cell.
On replication, it forms DNA while on transcription, it forms RNA.	It is neither replicate nor transcirbe.
It is double helical in structure.	It has single helix.

CHEMISTRY IN THE SERVICE OF MAN

Chemistry has been playing very important role in human life form the very begnning many examples may be given but followings are important.

Polymers are high molecular weight substances consisting of large molecules of colloidal dimensions. These are called macromolecules and their molecular weight may vary from 10,000 up to several millions.

Macromolecules are built up from small molecules called manomers, by polymerization reacrtion, which is a union of two or more smaller molecules of similar or different types with or without elimination of water, etc., giving the formation of new C—C linkages etc.

Example, $nCH_2 = CHCl \rightarrow$

vinyl chloride

$$(—CH_2—\underset{\displaystyle Cl}{\underset{|}{CH}}—)_3$$

polyvinyl chloride

In it the manomer molecules simply add together to form chains. Addition polymerization is reduced by ions or free radicals. The polymer thus obtained is called addition polymer Example

$CH_2 = CH_2 + CH_2 = CH_2 + CH_2 = CH_2 + \cdot \rightarrow \ldots$

ethene

$$\ldots(—CH_2—CH_2—\ldots)_n$$

(polythene)

$CF_2 = CF_2 + CF_2 = CF_2 + \ldots \rightarrow$

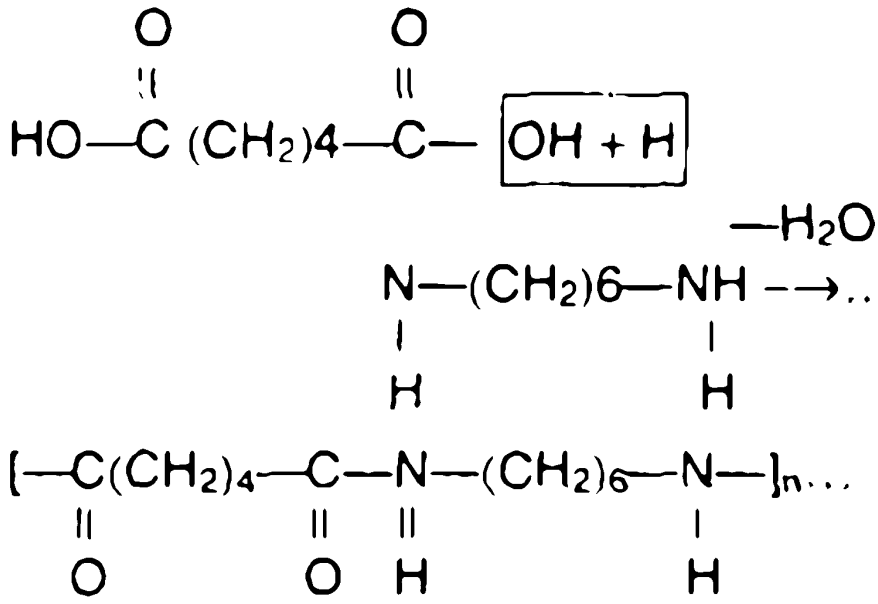
$$(—CF_2—CF_2—CF_2\ldots)n$$

tetrafluoro ethylene — teflon

Example. Polyvinal chloride (PVC), teflon, synthetic rubber etc.

Condensation polymerisation. is a type of polymerisation, the monomer

molecules join together with a simultaneous loss of small molecules (H_2O, HCl, HCN etc.) example the condensation of adipic acid with hexamethylene diamine forms Nylon–66 (a polyamide).



(nylon 66)

Polythene. This is an addition polymer and is made from ethylene or treating it to a high pressure (1000 atom) and at a temperature of about 730 K. The reaction is initiated by oxygen or peroxide.

$$n CH_2 = CH_2 \rightarrow (—CH_2—CH_2—)n$$

ethylene polyethene

It is used in making pipes, buckets, and in making laboratory apparatus films etc.

Polyvinyl chloride. (PVC) is obtained from vinyl chloride $CH_2 = CHCl$ and is used in the manufacture of plastic dolls hand bags, curtain cloths, etc. It is also used for insulating electrical apparatus.

The formula for PVC is

$$-(CH_2-\underset{\displaystyle Cl}{\underset{|}{CH}}-CH_2-\underset{\displaystyle Cl}{\underset{|}{CH}}-)_n$$

PVC

Teflon. This is also an additional polymer and is obtained from tetra fluro ethylene ($CF_2=CF_2$)

$$n(CF_2 = CF_2) \rightarrow (-CF_2-CF_2)$$

Teflon

This is used to resist the action of acids, alkalies and oxidising agents. It is mostly used in the manufacture of and non-lubricating bearings, gaskets, seals etc.

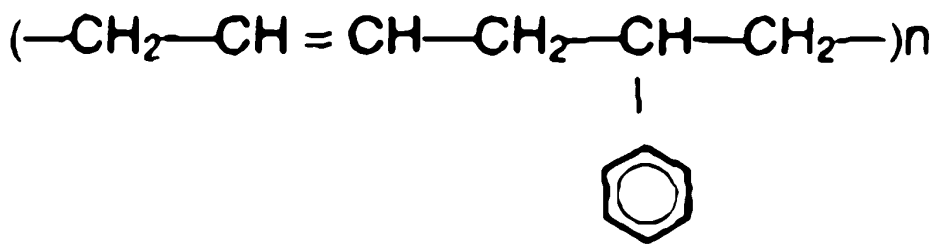
Synthetic rubber. Natural rubber is a polymer of isoprene. i.e.

2-methyl-1. 3-butediene,

$$CH_2 = C(CH_3)—CH = CH_2$$

In our life two types of rubbers are useful.

(a) SEP or GRS (**Buna-S**) **rubber**. It is also an addition polymer and is obtained from butadiene (75%) and styrene. It chemical structure is



This is used in belts, hose pipes, automobile tyres, flooring, rubber shoe soles.

Neoprene. This is the first American synthetic rubber obtained from chloroperene (2-chloro-1, 3-butadiene) by free radical addition polymerization. It is also used for making shoe heels, belts and stoppers. It is represented by—

$$[-CH_2-\underset{\displaystyle Cl}{\underset{|}{C}}=CH-CH_2-]_n$$

(polychloroprene)

(neoprene)

Nylon is a polyamide obtained by the condensation polymerization of adipic acid add tetramethylene diamine. This is used in fabrics ; carpets etc.

Orlon. Is an addition polymer and is obtained in the presence of a free radicals by the polymerization of acrylonitrile.

$$nCH_2=\underset{\displaystyle CN}{\underset{|}{CH}}_2 \rightarrow (-CH_2-\underset{\displaystyle CN}{\underset{|}{CH}}-)$$

(polyacry lonitrile)
(or lon)

It is also used as synthetic tire.

Dacron (terylene) is the polyster of tarephthalic acid and ethylene glycol. It is crease resistant and is durable can not damaged by moths and mildew.

Phenol for maldehyde resins Baklite. Bakelite is a thermosetting polymer obtained by the condensation of phenol and ormaldehyde and used for making fountain pens, phonograph records can be knobs, handles, electrical goods, etc. It is used as an insulator of electricity.

CAN is the short form of calcium ammonium nitrate ($Ca(NO_3)_2$ NH_4NO_3).

It is stable, safe and non-hygroscopic fertilizer. ITO nitrogen contant (22 per cent).

Chemical fertilizers are compounds which are mixed in the soil to provide essential nutrients to plants.

Fertilizers are of mainly three types:

(I) nitrogenous (N).

(II) phosphatic (P).

(Iii) potash (K).

Nitrogenous is the content of Ammonium sulphate Urea Calcium ammonium nitrate (CAN) and Calcium cyanamide ($CaNCN$)

Phosphatic is the constituent of Superphosphate and Triple superphosphate.

While Potash Muriate of potash (KCl)

and Potassium sulphate.

Superphosphate is a phosphatic fertilizer and is a mixture of calcium dihydrogen phosphate [$Ca(H_2PO_4)_2$] and calcium sulphate [$(CaSO_4)$]. It is prepared by the action of H_2SO_4 on calcium phosphate

$$Ca_3(PO_4)_2 + 2H_2SO \rightarrow Ca(H_2SO_4)_2 + 2CaSO_4$$

Soap. Ordinary soap is sodium or potassium salt of a fatty acid such as palmitic ($C_{15}H_3$ COOH), stearic ($C_{17}H_{33}COOH$) or oleic ($C_{17}H_{33}COOH$).

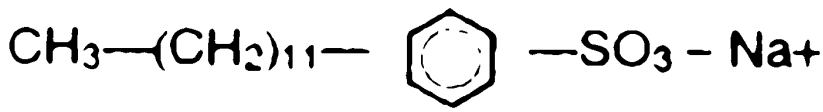
Soap acids are obtained by the saponification of fats and oils.

$$\begin{array}{l} CH_2COOC_{17}H_{33} \\ | \\ CHCOOC_{17}H_{35} \\ \text{fat} \end{array} + 3NaOH \rightarrow \begin{array}{l} CH_2OH \\ | \\ CHOH \\ | \\ CH_2OH \\ \text{glycerol} \end{array} + \underset{\text{Sod. stearate (Soap)}}{3C_{17}H_{25}COONa}$$

Soap is a detergent. Its molecule has a polar end, —COO-Na+ and a non-polar end (end carbon chain). The polar end is water soluble and non-polar end is oil-soluble soaps have many uses in lives.

Synthetic detergent. are synthetic compounds which are used for washing purposes. They contain salts of sulphonic acids or alkyl hydrogen sulphates. Detergents are of 4 types:

Alkyl benzene sulphonates (anionic)



Alkyl sulphates (anionic)—

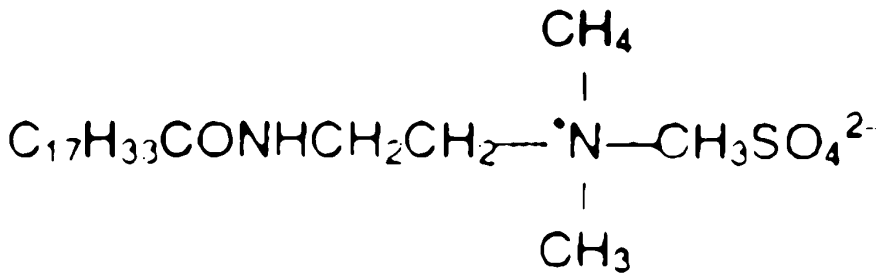
$CH_3—(CH_2)_{10}—CH_2OSO_3 - Na^+$;

Sodium lauryl sulphate

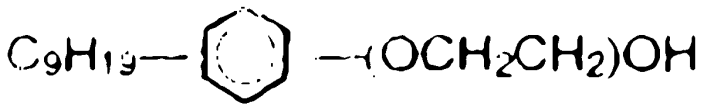
$CH_3—(CH_2)_{16}—CH_2OSO_3^- Na^+$;

sodium stearyl sulphate

Cationic detergent as like sapamine.



Non-ionic detergent like ethoxylate nonyl phenol



Antiseptics. Antiseptic is a substance which prevents growth of bacteria or may even kill them.

It does not harm the living human tissues and can easily be applied on cuts and wounds.

These are salvon mercuro chrome, $KMnO_4$, acriflavin, boric acid.

Disinfectants. Though these kill bacteria but are harmful to human, tissues. Disinfectants are used for sterlization of inanimate objects like instruments drains, cloths, floors etc.

Drug is a chemical substance administered to a person or animal to prevent or cure diseases and also to enhance physical or mental welfare.

Germicides. Germicide is a general term for all substances which can destroy [illegible] fungi, germs and viruses. Antisep-

tics, disinfectants and germicides are metabolic poisons or strong oxidising agents for organic matter e.g.

Poisons $HgCl_2$ (0.1% soln), mercurochrome, formaldehyde, phenol cresol, acriflavine $AgNH_3$ and boric acid.

Oxidising agents ($KMnO_4$ (1% solution.), chlorines solution, bleaching powder, tincture of iodine, iodoform, (H_2O_3 3% solution).

Antibiotics. Chemotherapeutic substances are obtained as metabolic products from some specific organisms (bacteria, fungi and moulds) and are used to destroy other micro-organism. Example

Pencillin. (Cures pneumonia, bronchitis, sore throat etc).

Tetracyclin. terramycin. These are effective against different type of harmful micro-organisms.

Chloromycetin, is used for the treatment of typhoid.

Steptomycin, is used for tuberculosis.

Classes of Drugs

Class	*Function*	*Example*
Anti-pyretics	Bring down body temperature in high fever	Aspirin, phenacetin, paracetamol
Antide-presents	Produce feeling of well being, enhance self confidence	Tofranil, mendarex, benezedrine
Analgesics	Relieve pain	Aspro, novalgin, anacin, saridon,
Narcotics	Produce sleep and unconscious-ness	Morhine, heroin
Antibiotics	Kill micoro-organisms, treatment of various diseases	Penciline, chloromycetin, streptomycin, tetracyclin, terramycin, Ampicillin.
Psy-chadelic drugs	Disturb vision and hearing cause hallucination	LSD (lysergic acid diethyl amide)

General Anaesthetic.	Produce insensibility to pain in a limited area.	Ether, N_2O, pethidine cyclopropane, morphine.
Sulpha drugs.	Kill micro-organisms.	Sulphanilamide, sulphaguanidine, sulphathiazole.
Birth control pills.	Control birth	Norethin drorie, mestranol.

Chemistry has provided the following amenities for our life.

Air conditioning. Liquid ammonia and liquid sulphur dioxide are used for air conditionings. These are all chemical substance Articles of daily use paper, soap, cosmetic dyes, oil and perfomes, All cosmetics are the product of chemistry Pecestrations All items of decration as fibre glass, wall paper, plastic sheets, household articles are being provided by chemistry.

Entertainment—Calluloid, a chemical product is being utilized for own entertainment. It is used for making films. Building materials chemistry has given us steel,

glass cement etc. as building materials. Chemistry has solved our residential problems.

Metals - Metals like gold, silver, copper, platinum, aluminium, zinc, coins, ornaments, machinary parts are all being prepared by the formaules of chemistry. Textiles cotton, silk, wool, synthetic fibre such as nylon, rayon, terylene, orlon, are the boon of chemistry.

Latex. Latex is a milky liquid obtained from the rubber tree. This contains about 30% to 40% of rubber in the form of a colloidal solution in water.

Extraction of latex. Rubber trees contain a network of narrow tubes called latex vessels. A cut is made in the bark to get the latex. When the bark is cut latex starts coming out of the tree and then it is collected in vessels through a spout attached to the tree.

Extraction of rubber from latex. The latex obtained latex from the rubber tree is diluted with water to reduce the concentration of rubber to about 12 to 20%. A very

dilute solution of acetic acid is then added to latex to coagulate rubber. The coagulated rubber is separated from the solution and then washed and dried.

Vulcanisation of raw natural rubber. It is the process of heating natural rubber with sulphur to improve its properties

Composition of vulcanised rubber

Anti-oxidant (Diphenylamine)	(1 part)
Natural rubber	(100 parts)
Carbon black (Filler)	(50 parts)
Sulphur	(3 parts)

Uses. vulcanised rubber is used for the manufacture of rubber bands and gloves. It is also used for the manufacture of rubber tubing.

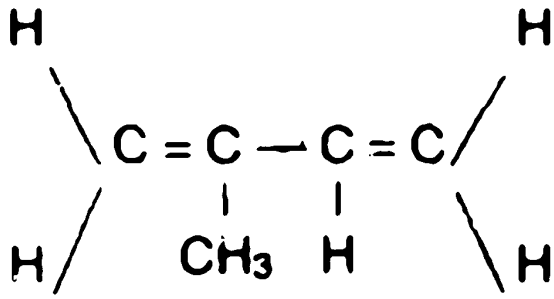
Filler. A solid substance added to rubber during vulcanistion to increase its srength and to reduce the cost is known as filler. Carbon black is used as a filled for natural rubber.

Anti-oxdant. A substance which is added to rubber during vulcanisation to

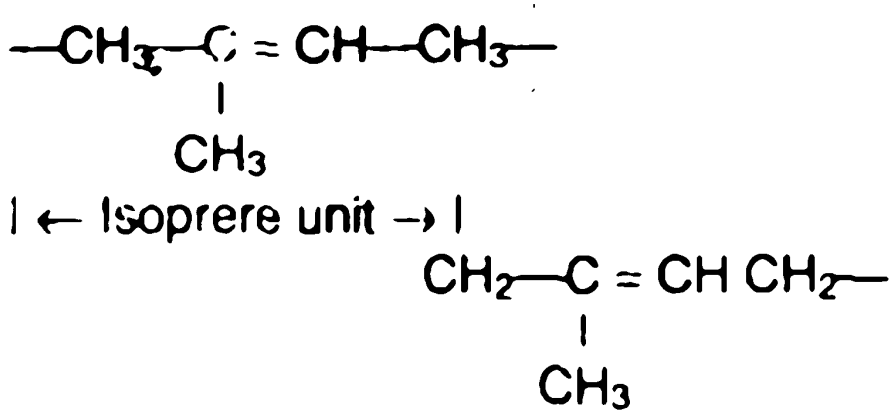
protect it from deterioration on exposure to air is called an anti-oxidant.

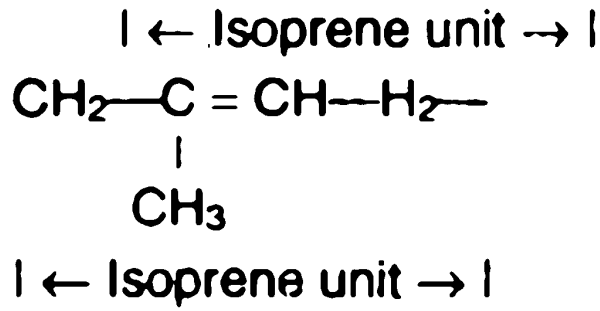
Diphenylamine $(C_6H_5)_2$ NH is used as an anti-oxidant for rubber.

Basic unit of natural rubber. Actually basic unit of natural rubber is isophrene C_5H_8. and its structural formula is—



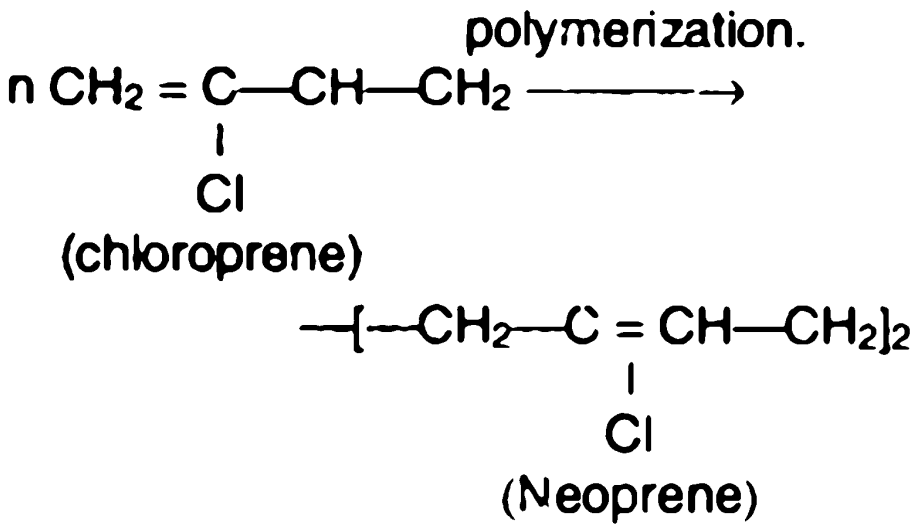
Unit of isoprene. There may be 11000 to 20,000 isoprene units in the polymer chain of natural rubber. Chemically it may be written as



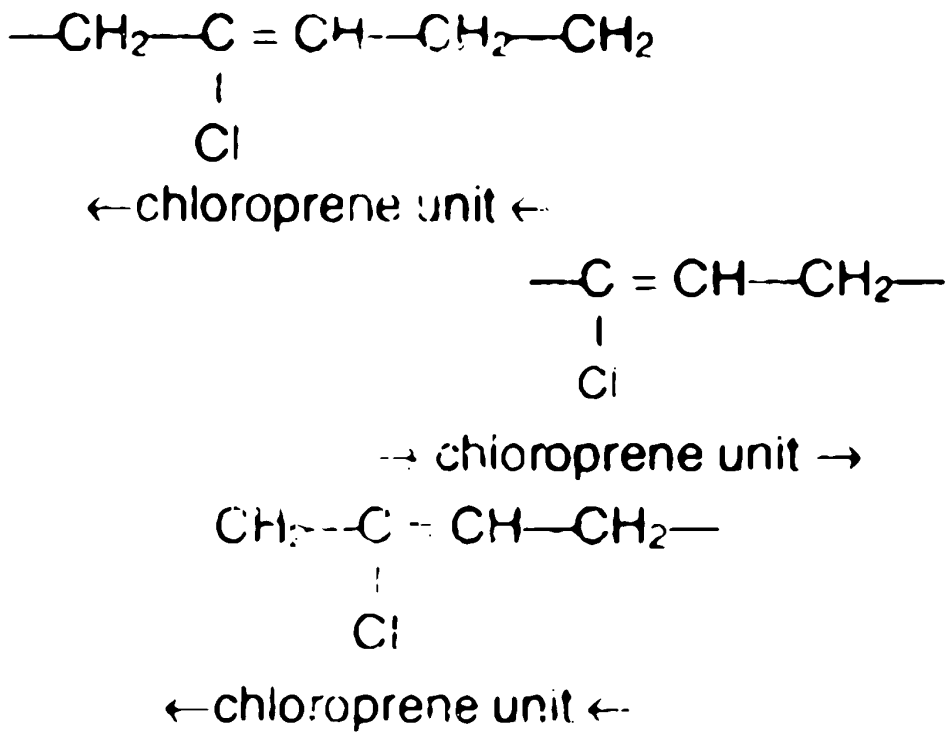


Synthetic Rubber. This term has been given to artificial rubber. Synthetic rubbers are not identical with natural rubber but resemble with it is many properties. The two important synthetic rubbers are neoprene and thiokol.

Neoprene is an important synthetic rubber. It is a polymer of chloroperene Neoprene is prepared by the polymerization of chloroprene i.e.



The structure of this synthetic rubber neoprene is similar to that of the natural rubber. A part of the neoprene structure as shown below



Uses of neoprene

It is used for making petrol delivery hoses (flexible pipes) and for making insulation of electric wires cables.

Thiokol is an important synthetic rubber. It is a polymer of ethylene polysulphide.

Thiokol rubber is prepared by the con-

densation of 1,2-dichloro ethane with sodium polysulphide:

$$Cl—CH_2CH_2—Cl + Na—S—S—Na + Cl$$

1,2 dichloro ethane sodium polysulphide

$$—CH_2—CH_2—Cl \rightarrow$$

1,2 dichloro ethane

$$—\{—CH_2—CH_2—S—S—CH_2—CH_2—\}_n$$

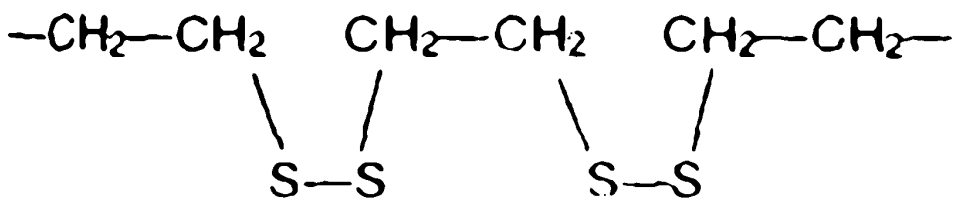
Thiokol

$$\rightarrow 2m\ NaCl$$

(A polymer of ethylene polysulphide)

Just like natural rubber, thiokol rubber has a long chain in which the units like $—CH_2—CH_2—S—S—CH_2—CH_2—$ are repeated.

A part of the polymer chain of thiokol rubber can be written as



Polymer chain of thiokol rubber

Below the table presence a comparison of all these quaiities.

Properties	Type of rubber		
	Natural	*Neoprene*	*Thiokol*
Tensile strength (pounds per sq. inch)	3000	3000	1200
Elongation at break point (in %)	800	800	400
Oxygen and ozone resistance	Poor	Good	Good
Tear resistance	Excellent	Good	Poor
Abrasion resistance	Excellent	Excellent	Poor
Useful temperature range	–40°C to 100°C	–40°C to 100°C	–40°C to 100°C
Solvent resistance	Poor	Good	Good

Natural fibres. There are three important natural fibres. (i) cotton (ii) wool (iii) silk. These are used for making fabrics.

Cotton is made up of carbon, hydrogen and oxygen elements only but woop and silk

also contain nitrogen in addition to carbon, hydrogen and oxygen.

Cotton [or cellulose $(C_6H_{10}O_5)n$], wool and silk are all natural polymers.

The garments of natural fibre like cotton silk, wood do not retain the crease. They shrink on ordinary washing and can catch fire easily. But those man-made fibres which are prepared from natural raw material (for example viscose rayon) is from a natural raw material called cellulose.

These man-made fibres are purely synthetic and do not acquire any-natural raw materials, (for example nylon and terylene are purely synthetic fibres.

Nylon. It is a synthetic fibre obtained by condensing adipic acid with hexamethylene-diamine.

$$HOOC—(CH_2)_4—COOH + H_2N—(CH_2)_6$$

Adipic acid — Hexamethylanediamine

(n molecules) — (n molecules)

$—NH_2$

$$-NH_2 \xrightarrow{\text{Polymerization}} HOOC-[-(CH_2)_4-CO-NH-(CH_2)_6-]-NH_2 + nH_2O$$

Nylon
(A polyamide)

Nylon fibre. Nylon has very low degree of moisture absorption. It has dry dip properties.

Nylon fibre gives light and very strong threads. Thus nylon is used for making of fishing nets, parachute fabric and climbing cords.

It is very flexible and retains its original shape after use.

On blending with wool, nylon increases its strength and resistance against abrasion.

Artificial silk. Artificial silk prepared from cellulose is called rayon of the various varieties of rayon, viscose rayon is the most common.

The product is treated with carbon-disulphide to give a yellow solid.

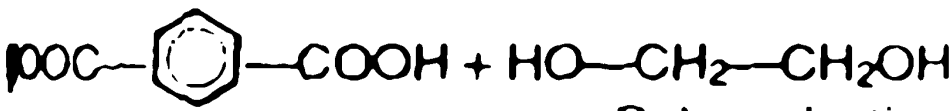
Cellulose in the form of wood pulp is treated with a strong solution of caustic soda and then dried.

The yellow solid is dissolved in dilute austic soda solution.

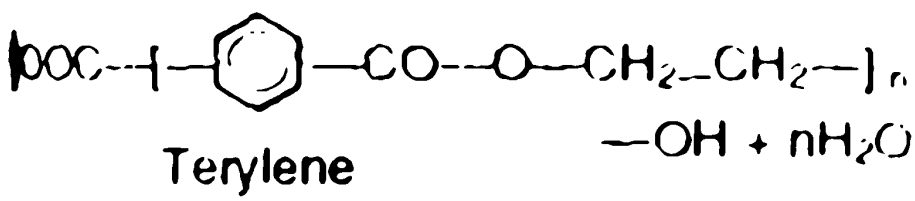
Solution from (iii) is passed through a pinneret into dilute hydrochloric acid to roduce fibres.

Fibres are then woven to produce artifi- al silk textiles.

Terylene. is a synthetic fibre prepared om terephthalic acid and ethylene glycol by eans of condensation polymerization.



Terephthalic acid Ethylene glycol



Terylene

Properties. Terylene is strong and ther oplastic, has high abrasion resistance

Terylene has excellent wrinkle resi- nce and absorbs very little moisture

Terylene is not attacked by ordinary chemicals or biological agents.

Preparation of synthetic fibres. The raw material dissolved in some solvent or in the molten state is passed through a spinneret. In this device the material passes through very fine holes and long fibres are drawn. Temperature and other conditions are adjusted in such a way that the fibres drawn from the holes are stabilised to retain their shape.

Tensile strength. The tensile strength of synthetic fibres can be increased by slowing down the speed at which the fibres are drawn through the holes in the spinneret and stretching the newly formed fibre (filaments) as much as possible without their breaking.

Comparsion of cotton, wool silk and artificial fibre.

Cotton. They burn vigorously and give smell of burning paper. No bead is left afterwards.

Wool silk. They burn but burning is not vigorous. A smell of burning feathers will be

noted. No bead is left afterwards. Synthetic fibres from proteinous natural material fall into their category.

Artificial fibres. These burn very slowly. A bead is formed due to the melting of the material of the fibre. Terylene, Nylon and Rayon (from cellulose acetate) fall into this category.

Coal. Coal is a mixture of carbon compounds and free carbon. Some nitrogen and sulphur compounds are also exits in coal.

Formation of coal. Coal is formed by the decomposition of plants and trees buried under the surface of earth long-long ago.

A slow chemical process of the conversion of wood into coal is called carbonisation.

There is a variety of coal particularly —

Peat	contains 60%	Carbon
Lignite (soft coal)	" 70%	"
Bituminous (house hold coal)	" 80%	"
Anthracite (hand coal)	" 90%	"

Uses. It is used as a fuel and is used in manufacture of fuel gases like coal gas. It is

used in the manufacture of synthetic petrol. It is used to make coke.

It is used as a source of organic compounds like toluene benzene.

Coke is 98% carbon or we can say coal minus volatile material is coke. Coke is used as a reducing agent in metallurgy. It is used as a fuel for making fuel gases like water gas and producer gas.

It is also used to prepare calcium carbide.

Dry distillation of coal. Coal is heated at temperature above 1000°C in the absence of air is retorts of fire proof clay. The type of purified coal gas contains the following constituents.

Methane—about 35% by volume

Hydrogen—about 50% by volume

Carbon monoxide—about 8% by volume

napthalene ethylene benzene acetylene	4% by volume

nitrogen
carbon dioxide } 1% by volume

It's solid residue left behind is known as coke.

Petroleum is a dark coloured oily liquid with a characteristic smell. It is lighter than water and insoluble in it. It is a mixture of hydrocarbons (solid liquid as well as gaseous). It is formed by decomposition of animal and plants remains inside the earth

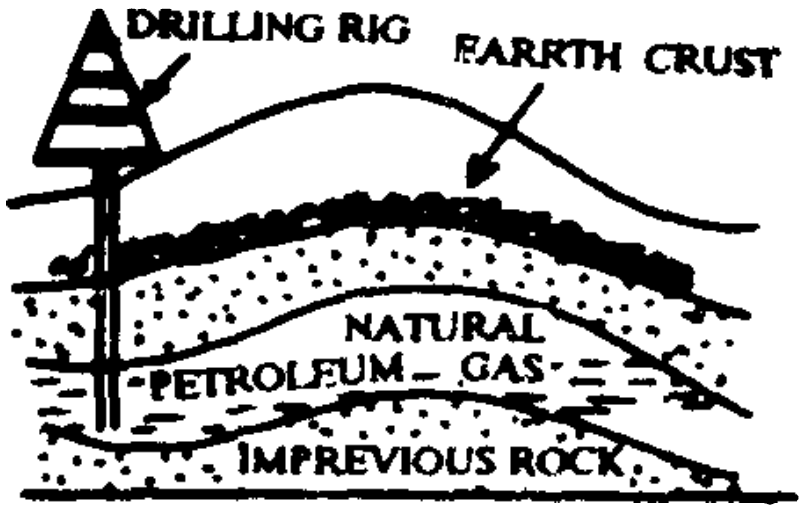


Fig.

Petroleum occurs in large quantities in the depths of the earth between certain

sedimentary rocks layers. Huge quantities of gas (Natural gas) also occur alongwith petroleum under the earth. Bombay high (off-shore area). Ankleshwar and Kalol in Gujarat.

Rudrasagar in Assam are the places in India where its found.

Refining. The process of separating crude petroleum into more useful fractions by fractional distillation is known as refining. Petroleum is heated to above 400°C and the vapours are passed from bottom upwards in a fractionating column. Fractions condensing at different boiling ranges are collected separately.

The various fractions obtained by fractional distillation of crude petroleum oil are: gas, gasoline or petrol; kerosene, gas oil and diesel oil lubricating, vaseline oil and paraffin wax.

Refineries in India. meat Bombay, Diyboi, Visakhapatnam, Gauhati, Koyali, Madras, Cochin, Holida, Barauni and Mathura.

Organic compounds prepared from the hydrocarbons obtained from natural gas and petroleum are called petrochemicals.

Fractions obtained by refining of Petroleum.

Fraction	Molecular Composition (Alkanes present)	*Boiling range*	*Uses*
Gas	C_1 to C_4	16.4° to 30°C	Gas is used as a fuel; in the production of carbon black and hydrogen in the production of liquified petroleum gas (LPG) and in the manufacture of gasoline (petrol) by polymerization.

Gasoline or (Petrol)	C_5 to C_{12} 30°C	175°C	Gasoline is used as a motor fuel; as a solvent; for dry cleaning and for making petrol gas.
Gas oil and diesel oil	C_{13} to C_{18}	250° to 400°C	Used as furnace fuel; fuel for diesel engines and for making petrol by cracking.
Kerosene	C_{12} to C_{16}	175° to 275°C	Kerosene is used as a household fuel; for lighting and for making oil gas.
Lubricating oil	C_{16} to C_{50}	Above 350° C	Lubricating oil is used for lubrication. Vaseline is used for making toilet goods and grease. Paraffin wax is used for making candles etc.

Fuel. Any material which may be burnt in air to produce heat and light is known as a fuel.

Characteristics of a good fuel are as follows:

It should be readily available

It should be cheap.

It should produce large amount of heat per unit mass.

It should not produce during burning any harmful by-product like poisonous materials or irritating fumes etc.

It should be conveniently handled and transported.

It should not leave any residue or ash after burning.

It should burn in way that can be under control.

There are three types of fuels.

Solid fuels. Coke, wood, coal, charcoal and paraffin wax.

Liquid fuels. Petrol, alcohol, kerosene, diesel, liquid hydrogen.

Gaseous fuels. Natural gas, coal gas, liquified petroleum. gobar gas, water gas etc.

Wood. is a solid fuel. Trees are the sources of wood. Wood charcoal is obtained by destructive distillation of wood (heating in absence of air). It is composed of compounds having mainly carbon, oxygen, hydrogen and nitrogen.

Kerosene oil/petrol. These are liquid fuels. They are obtained as different fractions during distillation of petroleum, kerosene oil: C_{10}—C_{16}. petrol: C_6—C_9.

LPG contains largely butane and isobutane. It is obtained as a by-product during petroleum refining. They are called petroleum gas (LPG) because they are liquefied under pressure for strage.

Coal gas. is a mixture of methane, hydrogen and carbon monoxide. It is prepared by destructive distillation of coal.

Natural gas. It contains methane and ethane as major constituents and is obtained when certain wells are bored in gas breaking pockets in rocks, where it is found associated with petroleum.

Paraffin wax. is a solid fuel. It is obtained during refining of petroleum and is consist of several heavier hydrocarbons.

Water gas. is also a gaseous fuel, is mixture of hydrogen and carbon monoxide. It is obtained by passing super heated steam over heated coke.

$$\underset{\text{(red hot)}}{C} + \underset{\text{steam}}{H_2O} \longrightarrow \underbrace{H_2O + CO}_{\text{water gas}}$$

Producer gas. is a gaseous fuel. It may be obtained by burning coal in a mixture of air and it is a mixture of carbon monoxide, nitrogen.

Fuels used in rockets are called propellants because they supply enough energy for propulsion of rockets in space. **Propellant** are fuels which supply enough energy for propulsion of rockets in space.

These are of two types: **Solid propellants** consists of a mixture of hydrocarbon and an oxidiser like chlorate, perchlorate (or a nitrate).

Liquid propellants are mixture of fuels like alcohol hydrazine, liquid hydrogen etc. mixed with oxidising agents such as liquid oxygen and hydrogen peroxide.

Typical liquid propellants are : (1) liquid hydrogen and liquid oxygen. (2) hydrazine and nitric acid.

The fuel used in rockets contain the fuel as well as the oxident, the oxident enhances the rate of combustion of fuel. Ordinary fuel used in

Decimal multiples and submultiples to be used with S units

Sub-multiple	*Prefix*	*Symbol*	*Multiple*	*Prefix*	*Symbol*
10^{-1}	deci	d	10	deca	da
10^{-2}	centi	c	10^{2}	hecto	h
10^{-3}	milli	m	10^{3}	kilo	k
10^{-6}	micro	μ	10^{6}	mega	M
10^{-9}	nano	n	10^{9}	giga	G
10^{-12}	pico	p	10^{12}	tera	T
10^{-15}	femto	f	10^{15}	peta	P
10^{-18}	atto	a	10^{18}	exa	E

Conversion of units to SI units

From	To	Multiply by
In	m	2.54×10^{-2}
ft	m	0.3048
sq.in	m^2	6.4516×10^{-4}
sq.ft	m^2	9.2903×10^{-2}
cu.in	m^3	1.63871×10^{-5}
cu.ft	m^3	2.83168×10^{-2}
litre)	m^3	10^{-3}
gal(lon)	m^3	4.54609×10^{-3}
gal(lon)	1 (litre)	4.5609
miles/hr	ms^{-1}	0.47704
km/hr	ms^{-1}	0.27778
lb	kg	0.453592
g/cm^3	kg m^{-3}	10^3
lb/in^3	kg m^{-3}	2.76799×10^4
dyne	N	10^{-5}
gf	N	9.80665

poundal	N	0.138255
lbf	N	4.44822
mm Hg	Pa	133.322
atmos-phere	Pa	$1.013\,25 \times 10^{5}$
hp	W	745.7
erg	J	10^{-7}
eV	J	$1.602\,10 \times 10^{-19}$
kWh	J	3.6×10^{6}
cal	J	4.1868

The solar system

Planet	*Equatorial diameter (km)*	*Mean distance from (sun 10⁶ km*	*Sidereal period*
Mercury	4878	57.91	87.969 days
Venus	12104	108	224.7 days
Earth	12756	149.60	365.256 days
Mars	6792	227.94	686.980 days

Jupiter	142 700	778	11.86 years
Saturn	120 800	1430	29.46 years
Uranus	51 800	2869.6	84.01 years
Neptune	49 400	4496	164.8 years
Pluto	3500	5900	248.4 years

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